Approved: 2018-05-23

Measurement System Identification: Hybrid—Inch—Pound and Metric

NASA TECHNICAL STANDARD

National Aeronautics and Space Administration

NASA-STD-8719.12A

Approved: 2018-05-23
Superseding NASA-STD-8719.12

SAFETY STANDARD FOR EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

Reply to the attention of:

DEP/FAP/LP

APR 2 5 2018

James D. Polk, DO, MS, MMM, CPE, FACOEP
Chief Health and Medical Officer
Designated Agency Safety and Health Official
National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

Dear Dr. Polk:

Thank you for submitting the National Aeronautics and Space Administration's (NASA's) revised supplementary safety standard, *NASA–STD-8719.12A, Safety of Explosives, Propellants, and Pyrotechnics* to the Occupational Safety and Health Administration (OSHA). The supplementary standard includes requirements for NASA operations that use energetic liquids/materials as propellants for space launch vehicles. It also addresses NASA's use of other energetic materials, such as explosives, small arms ammunition, and explosive actuators, covered by OSHA's standard at 29 CFR 1910.109, *Explosives and Blasting Agents*. You requested that OSHA review the revised and updated supplementary standard, and noted that there continues to be no appropriate OSHA standard addressing the working conditions specific to NASA's use of the energetic materials.

Background

According to the basic program element at 29 CFR 1960.18(a), a federal agency must adopt relevant emergency temporary and permanent supplementary standards when no appropriate OSHA standard exists to cover a particular working condition. After developing a supplementary standard, Section 1960.18(b) requires the agency to provide it to OSHA prior to its official adoption at agency worksites. After reviewing the provided draft supplementary standard, OSHA will notify the submitting agency whether or not it can adopt or implement the standard.

NASA first proposed adopting a supplementary standard for explosives, propellants, and pyrotechnics in 1993, which OSHA approved on December 9 of that year. In October 2008, NASA requested approval of a revised version of the same standard. OSHA approved the revised standard on January 31, 2011.

On November 13, 2017, NASA submitted for OSHA's review a revision to the 2008 approved supplementary standard. NASA explained that, while the revision incorporated few technical changes, other modifications included updating the format, adding training requirements for specific job classifications, adding metric units to tables, eliminating redundancies with other regulations, clarifying language, and removing requirements that were inapplicable. In addition,

NASA noted that, per the requirements in Section 1960.18, it had made the document available for review to relevant interested parties. NASA received no comments from employee representatives on the revised supplementary standard.

OSHA reviewed the initial (provided) revision of NASA-STD-8719.12A and, on January 30, 2018, met with NASA personnel to discuss the document. Following the January 2018 meeting, NASA incorporated several suggestions from OSHA into a final draft revision. Using that final draft, OSHA assessed the latest supplementary standard revision and compared it for consistency with OSHA standards and enforcement policy.

OSHA Response

In accordance with the requirements in Section 1960.18, OSHA has reviewed the most recent final draft of the revised supplementary standard. The agency notes that there continues to be no OSHA standard that addresses the working conditions at NASA worksites regarding the use of energetic liquids/materials as propellants for space launch vehicles. Additionally, OSHA's standard at 29 CFR 1910.109, *Explosives and Blasting Agents,* does not include requirements (such as specifications for *inhabited building distances*) which are included in NASA's supplementary standard. However, where the revised supplementary standard references 29 CFR 1910.109, such references are consistent with that OSHA standard's requirements. Accordingly, at this time, OSHA finds no inconsistency between the most recent final draft version of NASA-STD-8719.12A, *Safety of Explosives, Propellants, and Pyrotechnics*, and OSHA standards and enforcement policy.

Thank you for your interest in occupational safety and health. OSHA requirements are set by statute, standards, and regulations. This letter constitutes OSHA's comparison of, and decision regarding, only the documents, standards, and policies discussed above. Please note that our guidance may be affected by changes to OSHA rules and that from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at www.osha.gov. If you have any questions, please feel free to contact Ms. M. Renee Carter, Acting Director for OSHA's Office of Federal Agency Programs at (202) 693-1972 or carter.m.renee@dol.gov.

Sincerely,

Thomas Galassi

Thomas Galassi, Director
Directorate of Enforcement Programs

DOCUMENT HISTORY LOG

Status	Document Revision	Approval Date	Description
Baseline		2010-01-29	Initial Release (Supersedes NASA-Safety Standard 1740.12).
Change	1	2011-11-17	Changes to sections 3.1, 4.25.9.1.12.5.1, 4.25.9.1.12.10, 5.53.4.4 and note #5 to Table XXXII.
Change	2	2011-12-12	Administrative change to add Requirement Hyperlinks to the SMARTS application.
Revision	A	2018-05-23	The Safety Standard for Explosives, Propellants, and Pyrotechnics, NASA-STD-8719.12, was revised to: a. Reflect current NASA standards formatting b. Update language for seeking relief from the stated requirements c. Add training requirements for ESOs and Ordnance Handlers d. Implement other clarifications and corrections
Change	1	2019-09-26	Updated section 4.19.4.11.1 for the exception of small arms ammunition and section 5.39.1 for the exception of Model Rockets. Changes made to correct typos and formatting. Changes made to reference NFPA 50 (receded) to NFPA 55.
Change	2	2021-03-18	Replaced references to NPR 8715.3 with NPR 8715.1 for section 4.12.1 and 1.3.2, which is now the directive that describes the process for requesting relief from Agency Institutional Safety Requirements. Updated the ordnance handler’s medical requirement to reflect the change from annual to biennial which was approved Oct 2018.

Status	Document Revision	Approval Date	Description
			Changes made to correct typos and formatting for section 4.3.1, 4.3.4, 4.9, 4.13.1(c), 4.14.1.(g), and 4.15.9.

This document is subject to reviews per Office of Management and Budget Circular A-119, Federal Participation in the Development and Use of Voluntary Standards (02/10/1998) and NPR 7120.10, Technical Standards for NASA Programs and Projects.

FOREWORD

This NASA Technical Standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods for safely handling and storing explosives and pyrotechnics at NASA Centers. These requirements have been endorsed as standard for NASA programs and projects and work at NASA Centers and facilities.

This NASA Technical Standard is approved for use by NASA Headquarters and NASA Centers and Facilities and may be cited in contract, program, and other Agency documents as a technical requirement. It may also apply to the Jet Propulsion Laboratory (JPL) and other contractors only to the extent specified or referenced in applicable contracts.

This NASA-STD was developed by NASA Headquarters Office of Safety and Mission Assurance and the NASA Center's Explosive Safety Officers. Requests for information, corrections, or additions to this standard should be submitted to the NASA, Office of Safety and Mission Assurance, by email to Agency-SMA-Policy-Feedback@mail.nasa.gov or via "Feedback" in the NASA Technical Standards System at https://standards.nasa.gov.

Harold W. Bell for
Terrence W. Wilcutt
NASA Chief, Safety and Mission Assurance

May 23, 2018
Approval Date

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SAFETY STANDARD FOR EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS

1. SCOPE

1.1 Purpose

1.1.1 The purpose of this standard is to prescribe the NASA safety standards and procedures for operations involving explosives handling and processing. This document provides a uniform set of standards for all NASA Centers involved in explosives storage, handling, and processing, and complies with the cardinal principle for explosives safety: Expose the minimum number of people to the minimum quantity of explosives for the minimum amount of time consistent with the operation being conducted.

1.1.2 This standard has been reviewed and approved for NASA use in accordance with 29 Code of Federal Regulations (CFR) 1960.18 as a supplemental standard to Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.109. For those areas not covered by 29 CFR 1910.109, this standard takes the place of OSHA regulations shall apply.

1.2 Applicability

1.2.1 This standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers and may be cited in contract, program, and other Agency documents as a technical requirement. This standard may also apply to the Jet Propulsion Laboratory (JPL) and to other contractors, grant recipients, or parties to agreements to the extent specified or referenced in their contracts, grants, or agreements.

1.2.2 This standard is applicable to facilities engaged in the development, manufacturing, handling, storage, transportation (on/offsite), processing, testing, or use of explosives, or assemblies containing explosives. The standard further provides requirements for operations involving explosives, propellants, pyrotechnics and energetic liquids used for and in space launch vehicles, aeronautic applications, rockets, missiles, associated static test apparatus, and ammunition items, and the safe management of such operations.

1.2.3 This standard does not govern bulk storage of hazardous gases used for standard industrial purposes (e.g., medical, welding) and non-propellant uses and systems involving liquid oxygen and liquid hydrogen.

1.2.4 The design of new explosives facilities shall conform to the requirements of NPR 8820.2 and the requirements in this document.

1.2.5 In this standard, document citations are assumed to be the latest version, unless otherwise noted.

1.3 Request for Relief

1.3.1 The primary objective of the NASA request for relief policy is to assure that NASA Headquarters maintains oversight of the Agency requirements while providing the Centers and

project managers with the authority and flexibility to accept reasonable risks necessary to accomplish their tasks.

1.3.2 Requests for relief shall adhere to the NASA request for relief policy in accordance with NPR 8715.1. In the assessment of the hazard analysis associated with a given situation, the principal effects of the explosive output to be considered are blast pressure, primary and secondary fragments, thermal hazards, and toxicity hazards.

1.3.3 All requests for relief, approved at the Center level, shall be submitted to the Chief, SMA.

1.3.4 The NASA request for relief process does not apply to federal, state, and local regulations (e.g., OSHA, Cal OSHA). Any variance of a federal or state/local regulation must be approved by the appropriate federal/state/local agency. The Chief, SMA shall review all proposed requests for relief of federal regulations before submittal for approval.

1.3.5 Explosives safety criteria in this standard specify minimum acceptable standards for explosives safety. Departure from this explosives safety standard shall only result from operational necessity and all risks associated with the departure must be completely understood and accepted by the appropriate approval authority.

2. APPLICABLE DOCUMENTS

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text. Use of more recent issues of cited documents may be authorized by the responsible Explosive Safety Officer. The applicable documents are accessible via the NASA Technical Standards System at https://standards.nasa.gov or may be obtained directly from the Standards Developing Organizations or other document distributors.

2.1 Government Documents

29 CFR 1910.104	Oxygen
29 CFR 1910.106	Flammable Liquids
29 CFR 1910.109	Explosives and Blasting Agents
29 CFR 1910.119	Process Safety Management of Highly Hazardous Chemicals
29 CFR 1910.132	Personal Protective Equipment
40 CFR 261	Identification and Listing of Hazardous Waste
40 CFR 262	Standards Applicable to Generators of Hazardous Waste
40 CFR 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
49 CFR 171-179	Hazardous Materials Regulations
NPR 1600.1	NASA Security Program Procedural Requirements

NPR 8715.1	NASA Safety and Health Programs
NASA-STD-8719.11	NASA Safety Standard for Fire Protection
AA-F-358J	Filing Cabinet, Legal and Letter, Size, Uninsulated, Security (including all amendments), General Services Administration, Revision J, 14 November 2012
AFMAN 91-201	Explosives Safety Standards, 21 March 2017
DDESB TP 15	Approved Protective Construction, Version 2.0, June 2004
DoD 6055.09	DoD Ammunition and Explosives Safety Standards, 2017
DOE-STD-1212-2012	DoE Standard Explosives Safety, June 2012
DOT-SP 7887	Special Permit Authorization, November 2011
MIL-C-43122G	Cloth, Sateen, Cotton, Flame Retardant Treated, Revision G, 16 September 1988
MIL-STD-398A	Shields, Operational for Ammunition Operations, Criteria for Design of and Tests for Acceptance, Revision A, 29 January 2014
NF 1791	Explosives Facility License, April 2010

2.2 Non-Government Documents

ASTM F2412-18	Standard Test Methods for Foot Protection, February 2018
A-A-59502	Commercial Item Description Plastic Sheet, Polycarbonate, 9 June 2000

IATA Dangerous Goods Regulations (DGR), 59th Edition, 1 January 2018

ICAO 9284	Technical Instructions for the Safe Transport of Dangerous Goods by Air, 2017 – 2018 Edition

Management Procedures for Organic Peroxide Forming Chemicals and other Explosive Chemicals, NMSU, Sept 2014

NFPA 25	Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, 2017 Edition
NFPA 30	Flammable and Combustible Liquids Code, 2018 Edition
NFPA 55	Compressed Gases and Cryogenic Fluids Code, 2020 Edition
NFPA 221	Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls, 2018 Edition

NFPA 495	Explosive Materials Code, 2018 Edition
NFPA 780	Standard for the Installation of Lightning Protection Systems, 2017 Edition
NFPA 1125	Code for the Manufacture of Model Rocket and High-Power Rocket Motors, 2017 Edition

2.3 Order of Precedence

2.3.1 This NASA Technical Standard establishes requirements for operations involving explosives, propellants, pyrotechnics and energetic liquids used for and in space launch vehicles, aeronautic applications, rockets, missiles, associated static test apparatus, and ammunition items and the safe management of such operations but does not supersede nor waive established Agency requirements found in other documentation.

2.3.2 For conflicts between this NASA Technical Standard and other requirements document, this document takes precedence, except in the case of Federal and applicable State/local regulations. Clarification and further resolution shall be resolved by the responsible Institutional Safety Authority and Institutional Safety Discipline Lead (i.e., ESO) in accordance with NPR 8715.1.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

AGS	Aboveground Sites
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
DDESB	Department of Defense Explosives Safety Board
DoD	Department of Defense
DOT	Department of Transportation
ECM	Earth-Covered Magazine
EED	Electro-Explosive Device
EELP	Explosives, Energetic Liquids, and Pyrotechnics
EID	Electrically Initiated Device
ELCG	Energetic Liquid Compatibility Group

EME	Electromagnetic Energy
EMR	Electromagnetic Radiation
EPA	Environmental Protection Agency
ERP	Effective Radiated Power
ES	Exposed Site
ESD	Electrostatic Discharge
ESO	Explosives Safety Officer
ESQD	Explosive Safety Quantity Distance
GOV	Government Owned Vehicle
GSA	General Services Administration
GSE	Ground Support Equipment
HD	Hazard Division
HAN	Hydroxylammonium Nitrate
HE	High Explosive
HFD	Hazardous Fragment Distance
HPM	High Performance Magazine
IATA	International Air Transport Association
IBD	Inhabited Building Distance
ICAO	International Civil Aviation Organization
ILD	Intraline Distance
IMD	Intermagazine Distance
IRFNA	Inhibited Red Fuming Nitric Acid
ISO	International Organization for Standardization
ISDL	Institutional Safety Discipline Lead
JP-10	Hydrocarbon Turbine/Ramjet Fuel
JPL	Jet Propulsion Laboratory
kPa	Kilopascal

LPS	Lightning Protection System
MCE	Maximum Credible Event
MILVAN	Military Van
MMH	Monomethylhydrazine
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NEW	Net Explosive Weight
NEWQD	Net Explosive Weight for Quantity Distance
NFPA	National Fire Protection Association
NPR	NASA Procedural Requirements
NSI	NASA Standard Initiator
OSHA	Occupational Safety And Health Administration
PBAN	Polybutadiene Acrylonitrile
PES	Potential Explosive Site
POV	Privately Owned Vehicle
PSI	Pounds Per Square Inch
PPE	Personal Protective Equipment
PTR	Public Traffic Route
PTRD	Public Traffic Route Distance
QD	Quantity Distance
RF	Radio Frequency
RH	Relative Humidity
SMA	Safety and Mission Assurance
SOP	Standard Operating Procedure
TNT	Trinitrotoluene
TP	Technical Paper
UDMH	Unsymmetrical Dimethylhydrazine

UN	United Nations

3.2 Definitions

Aboveground Magazine. Any building or structure, except for an operating building, used for the storage of explosives. Aboveground magazines are all types of above grade (not earth-covered) magazines or storage pads. This includes storage in trucks, trailers, railcars, or cargo aircraft.

Ammunition. Projectiles, such as bullets and shot, together with their fuses and primers that can be fired from guns or otherwise propelled.

Barricade. An intervening approved barrier, natural or artificial, of such type, size, and construction as to limit, in a prescribed manner, the effect of an explosion on nearby buildings or exposures.

Bay. A location (examples: room, cubicle, cell, work area) that affords the level of safety and protection appropriate to the material and activity involved.

Blast Overpressure. The pressure, exceeding the ambient pressure, manifested in the shock wave of an explosion.

Bonding. The process of controlling static electric hazards by connectiong two or more conductive objects together by means of a conductor so they are at the same electrical potential, but not necessarily at the same potential as the earth.

Cell (High Performance Magazine). A reinforced concrete storage area in an HPM, separated from other cells by a specially designed non-propagation interior wall, with a removable reinforced concrete lid forming the roof. The entire HPM is earth-bermed.

Change House. A building provided with facilities for employees to change to and from work clothes. Such buildings may be provided with sanitary facilities, drinking fountains, lockers, and eating facilities.

Classification Yard. A group of railroad tracks used for receiving, shipping, and switching railway cars.

Combustible Material. Any material which, when ignited, will sustain burning.

Compatibility. Chemical property of materials to coexist without adverse reaction for an acceptable period of time. Compatibility in storage exists when storing materials together does not increase the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Storage compatibility groups are assigned to provide for segregated storage.

Component. Any part of a complete item whether loaded with explosives (commonly called “live”), inert (not containing explosives), or empty.

Concurrent Operations. Operations performed simultaneously and in close enough proximity that an incident with one operation could adversely influence the other.

Counterpoise. A type of earth electrode system consisting of conductor cables buried around the structure to be protected. Generally, a counterpoise will have more surface area contacting the earth than ground rod systems.

Debris Hazard. A hazard resulting from any solid particle thrown by an explosion or other strong energetic reaction. For aboveground explosions, debris refers to secondary fragments.

Deflagration. A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source; a surface phenomenon with the reaction proceeding towards the unreacted material along the surface at subsonic velocity.

Demolition/Demilitarization (Demil). Disarm, burn, explode, neutralize or any other action that will render the explosive/explosive device free of hazardous materials.

Detonation. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure that proceeds through the reacted material toward the unreacted material at a supersonic velocity.

Dielectric Breakdown. The failure of the insulating property of a material when the dielectric strength of the material has been exceeded and current flows through the material.

Dividing Wall. A wall designed to prevent, control or delay propagation of a reaction involving explosives on opposite sides of the wall.

Dry Run. Rehearsal of a process without the presence of the associated hazard. The level of dry run activities is dependent upon effect of change to the hazard level of process.

Dunnage. Inert (though possibly flammable) material associated with the packaging, containerization, blocking and bracing, ventilation, stability of shipping, stacking and storage configuration.

Earth-Covered Magazine. An aboveground, earth-covered structure intended for the storage of explosives, pyrotechnics, propellant, or United Nations (UN) Class 1 hazardous materials that meets soil cover depth and slope requirements of this standard.

Electro-Explosive Device. An electrically-initiated device containing an explosive or pyrotechnic mixture. The output of the initiation is heat, shock, or mechanical action.

Electrostatic Discharge. The rapid and spontaneous transfer of electrical charge between two bodies at different electrical potentials.

Energetic Liquid. A liquid, slurry, or gel, consisting of, or containing, an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration, or detonation.

Energetic Material. A material consisting of, or containing, an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration, or detonation.

Explosive Donor. An explosion from a small device or explosive mass that may cause an adjacent explosive item or larger mass to react to yield measurable blast overpressure.

Explosive(s). Any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases that exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate.

Explosives Area. A restricted area specifically designated and set aside from other portions of a Center for the manufacturing, processing, storing, and handling of explosives.

Explosives Handler. Certified personnel authorized to physically handle explosives or pyrotechnic devices (outside of transportation or packing configuration) during storage, installation, inspection, or other use identified in an approved procedure.

Explosive Equivalent (TNT Equivalent). Amount of a standard explosive that, when detonated, will produce a blast effect comparable to that which results at the same distances from the detonation or explosion of a given amount of the material for which performance is being evaluated. It usually is expressed as a percentage of the total net weight of all reactive materials contained in the item or system. For the purpose of these standards, TNT is used for comparison.

Exposed Explosives. Explosives that are open to the atmosphere (such as unpackaged bulk explosives or disassembled or open components) and susceptible to initiation directly by static or mechanical spark, or create (or accidentally create) explosive dust, or give off vapors, fumes, or gases in explosive concentrations. This also includes exudation and explosives exposed from damaged items such as gun powder or rocket motors.

Exposed Site. A location exposed to the potential hazardous effects (blast, fragments, debris, and heat flux) from an explosion at a potential explosion site (PES). The distance to a PES and the level of protection required for an ES determine the quantity of explosives permitted in a PES.

Faraday Cap. A conductive metal cap that can be placed over the connector of an Electro-explosive Device (EED), e.g., an NASA Standard Initiator (NSI), to prevent inadvertent firing from exposure to an external electric field, i.e., radio frequency (RF) sources. Some, but not all, Faraday caps also short the bridgewire.

Firebrand. A projected burning or hot fragment whose thermal energy has the potential for transfer to a receptor.

Flammable Liquid. Any liquid having a flash point below 100 °F (38 °C) and a vapor pressure not exceeding 280 kPa (41 psia) at 100 °F (37.8 °C). This is the

definition as applied in this manual; it includes some materials defined as combustible liquids by the Department of Transportation (DOT).

Flash Point. The lowest temperature of the test specimen, adjusted to account for variations in atmospheric pressure from 101.3 kPa, at which application of an ignition source causes the vapors of the test sample to ignite under specified conditions of test.

Fragmentation. Breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. Fragments may be complete items, subassemblies, pieces thereof, or pieces of equipment or buildings containing the items.

Grounding. Electrical. In the context of this document, electrical grounding refers to connections between conductive materials and structure to the earth for protection from transients caused by ESD or lightning.

Hazard. Any condition that may result in the occurrence or contribute to the severity of an accident.

Hazard Analysis. Logical, systematic examination of an item, process, condition, facility, or system to identify and analyze the probability, causes, and consequences of potential or real hazards.

Hazardous Fragment. A hazardous fragment is one having an impact energy of 58 ft-lb or greater.

Hazardous Fragment Distance. The distance at which the density of hazardous fragments becomes 1 per 600 ft^2 (56 m^2)

Hazardous Material. Any material, item, or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other elements or factors.

Hazardous Waste. Any hazardous material that is discarded; disposed of; burned or incinerated; accumulated; stored; or used in a manner constituting disposal.

High Density Traffic. Traffic routes having 10,000 or more car and/or rail passengers per day, or 2,000 or more ship passengers per day.

High Explosive. An explosive (as denoted by its Class and Division; e.g., 1.1 through 1.6) in which the transformation from its original composition and form, once initiated, proceeds with virtually instantaneous and continuous speed through the total mass, accompanied by rapid evolution of a large volume of gas and heat, causing very high pressure and widespread shattering effect.

High Performance Magazine. An earth-berm, 2-story magazine with internal non-propagation walls designed to reduce the maximum credible event (MCE).

Holding Yard. A holding area for rail cars, trucks, or trailers used for temporary storage of vehicles containing explosives and other dangerous materials prior to shipment or transfer to a more permanent storage area.

Hot Work. Any operation requiring the use of a flame-producing device, an electrically heated tool, or a mechanical tool that can produce sparks or heat thereby providing an initiation stimulus.

Hypergolic. Self-igniting upon contact of fuel and oxidizer, without a spark or external aid.

Inert. Containing no explosive or chemical agents. Inert material shall show no incompatibility with energetic material with which it may be combined when tested by recognized compatibility tests.

Inhabited Building Distance (IBD). Minimum allowable distance between an inhabited building and an explosive facility. IBDs are used between explosives facilities and administrative areas, operating lines with dissimilar hazards, explosive locations and other exposures, and explosive facilities and Center boundaries, and define the restricted zone into which non-essential personnel may not enter.

Inhabited Buildings. A building or structure occupied in whole or in part by human beings, or where people are accustomed to assemble, both within and outside of Government establishments. Land outside the boundaries or local restrictive easement estate of NASA establishments is considered as inhabited buildings.

Institutional Safety Discipline Lead. Subject-matter-expert for the safety discipline they oversee who provide determination of compliance with requirements, equivalent levels of safety, and if a requirement is non-applicable.

Interchange Yard. A location set aside for exchange of rail cars or trailers between a common carrier and NASA.

Intraline Distance. The minimum distance allowed between any two operating locations or other designated exposures. This distance is expected to prevent propagation.

Intermagazine Distance. Distance to be maintained between two explosives storage locations.

K-Factor. K is a constant that is used to determine separation distance by the formula $d = KW^{1/3}$, where W is the weight in pounds. The formula can be used to determine required distances between potential explosive sites (PESs) and exposed sites (ESs). This will normally appear as the letter “K” followed by a number, for example “K8,” or “K30.”

Laboratory Operations. Experimental study, testing, and analysis of small quantities of energetic materials. Manufacturing processes with small quantities of materials are not included. Includes operations in a laboratory where the total quantity of 1.1 Class/Division explosive materials in the room does not exceed 200 grams. For

maximum quantities of other Class 1 Divisions, use TNT equivalencies where the comparable quantity for the Class 1 Divisions is determined by the TNT equivalency.

License. Formal documented permission from the ESO to operate a Licensed Explosive Location.

Licensed Explosive Locations. Locally licensed locations within NASA's control where explosives are used or stored for use.

Liquid Propellant. Liquid and gaseous substances (fuels, oxidizers, or monopropellants) used for propulsion or operation of rockets and other related devices.

Low Explosives. Propellants, which have a controlled rate of gas pressure, i.e. deflagration (subsonic).

Low Traffic Density. Traffic routes having less than 400 cars and/or rail passengers per day or less than 80 ship passengers per day.

Magazine. A structure designed or specifically designated for the storage of explosives.

Magazine Distance. Minimum distance permitted between any two storage magazines. The distance required is determined by the type(s) of magazine and also the type and quantity of explosives stored therein.

Mass Detonation/Explosion. Virtually instantaneous explosion of a mass of explosives when only a small portion is subjected to fire, severe concussion or impact, the impulse of an initiating agent, or to the effect of a considerable discharge of energy from an outside stimulus. Also refers to the instantaneous propagation of an explosion between multiple explosives items such that blast overpressure effects are combined into a single enhanced blast wave.

Maximum Credible Event (MCE). In hazards evaluation, the MCE from a hypothesized accidental explosion, fire, or agent release is the worst single event that is likely to occur from a given quantity and disposition of explosives, chemical agents, or reactive material. The event must be realistic with a reasonable probability of occurrence considering the explosion propagation, burning rate characteristics, and physical protection given to the items involved. The MCE evaluation on this basis may then be used as a basis for effects calculations and casualty prediction.

Medium Traffic Density. Traffic routes having 400 or more, but less than 10,000, car and/or rail passengers per day or 80 or more, but less than 2,000, ship passengers per day.

Net Explosive Weight. The total quantity, expressed in pounds, of explosive material or pyrotechnics in a container or device. The NEW may include the mass of the TNT-equivalent of all contained energetic substances based on Center policies.

Net Explosive Weight for Quantity Distance. The total quantity, expressed in pounds, of high explosive (HE) equivalency in each item to be used when applying

quantity-distance criteria. The NEWQD is equal to the NEW unless hazard classification testing has shown that a lower weight is appropriate for Quantity Distance (QD) purposes.

Non-essential Personnel. Personnel not essential to, or involved with, the immediate operation presenting the energetic materials hazard.

Non-mass Explosion. Partial explosion of a mass of explosives when only a small portion is subjected to fire, severe concussion or impact, the impulse of an initiating agent, or to the effect of a considerable discharge of energy from an outside stimulus. Also refers to sequential propagation of explosions of multiple items with time delays such that blast overpressure effects do not combine from each individual explosion.

Operating Building. Any structure, except a magazine, in which operations pertaining to manufacturing, processing, or handling explosives are performed.

Operating Line. Group of buildings used to perform the consecutive steps in the loading, assembling, modification, or salvaging of an item or in the manufacture of an explosive or explosive device.

Operational Shield. A barrier constructed to protect personnel, material, or equipment from the effects of a possible fire or explosion occurring at a particular operation.

Operator. A person assigned to perform a specific, generally continuing function on a production, maintenance, or disposal line or operation. Typically, the functions are performed at workstations or areas defined in a Standard Operating Procedure (SOP).

Ordnance. Explosives, chemicals, pyrotechnics, and similar stores (e.g., bombs, guns and ammunition, flares, smoke, or napalm). The term is sometimes used interchangeably with “explosives”.

Oxidizer. A chemical (other than a blasting agent or explosive as defined in 29 CFR 1910.109(a) that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

Potential Explosive Site. Location of a quantity of explosives that will create a blast fragment, thermal, or debris hazard in the event of an accidental explosion of its contents. The distance to an ES determines quantity limits for ammunition and explosives at a PES.

Propagation. Communication of an explosion (detonation or deflagration) from one potential explosion site to another by fire, fragment, or blast (shock wave) where the interval between explosions is long enough to limit the total overpressure at any given time to that which each explosion produces independently.

Propellant. A solid, liquid, or hybrid chemical substance used in the production of energy or pressurized gas that is subsequently used to create movement of a fluid or to generate propulsion of a vehicle, projectile, or other object.

Public Highway. Any street, road, or highway not under NASA custody used by the general public for any type of vehicular travel.

Public Traffic Route. Any public street, road, highway, navigable stream, or passenger railroad. This includes roads on NASA Centers that are open to non-essential personnel or the public for thoroughfare.

Pyrotechnic Device. All devices and assemblies containing or actuated by propellants or explosives, with the exception of large rocket motors. Pyrotechnic devices include items such as initiators, ignitors, detonators, safe-and-arm devices, booster cartridges, pressure cartridges, separation bolts and nuts, pin pullers, linear separation systems, shaped charges, explosive guillotines, pyrovalves, detonation transfer assemblies (mild detonating fuse, confined detonating cord, confined detonating fuse, shielded mild detonating cord, etc.), thru-bulkhead initiators, mortars, thrusters, explosive circuit interrupters, and other similar items. These may be electrically (Electro-Explosive Device, EED) or mechanically initiated. (Note: OSHA defines pyrotechnics as any combustible or explosive compositions or manufactured articles designed and prepared for the purpose of producing audible or visible effects which are commonly referred to as fireworks.)

Quantity Distance. Quantity of explosives material and distance separation relationships which provide defined types of protection.

Restricted Area. Any area, usually fenced, at an establishment where the entrance and egress of personnel and vehicular traffic are controlled for reasons of safety.

Service Magazine. A building used for the intermediate storage of explosives materials not exceeding the minimum amount necessary for safe efficient production.

Small Arms Ammunition. Ammunition comprising a complete round, cartridge or its components, including bullets or projectiles, cartridge cases, primers/caps and propellants that are used in small arms not exceeding 12.7 mm (50 caliber or 0.5 inch) for rifle or pistol cartridges or 8 gauge for shotguns.

Solid Propellant. Solid compositions used for propelling projectiles and rockets and to generate gases for powering auxiliary devices. Contains both fuels and oxidizers, and various other chemicals used as burning rate controllers and binders.

Static Electricity. An accumulation of electrical charge on a conductive or dielectric material. Unbounded accumulation of electrical charge can result in high levels of potential difference leading to ESD events.

Static Test Stand. Locations on which liquid propellant engines or solid propellant motors are tested in place.

Storage Compatibility. A relationship between different items of explosives and other dangerous materials whose characteristics are such that a quantity of two or more of the items stored or transported together is no more hazardous than a comparable quantity of any one of the items stored alone.

Storage Magazine. A structure designed or specifically designated for the long-term storage of explosives or ammunition.

Surveillance Inspection. Periodic visual inspection of explosive stock to determine serviceability and/or storage conditions.

Temporary Holding Area. Designated areas for temporarily parking explosive laden transport trucks/railcars. QD and compatibility requirements apply.

Transient. A person with official business on a production line or operation but who is not routinely assigned to a specific limited location. Typically, transients are roving supervisors, quality assurance, safety personnel, or maintenance personnel. Official visitors are considered transients.

Unserviceable Explosive. An explosive material or device which is not currently qualified for its original intended purpose, but may be inspected and returned to service for its original intended purpose or may with proper analysis be used for another purpose, such as for demonstrations, research, testing, training, etc. Unserviceable materials and devices are not considered or managed as hazardous waste until the material(s) or device(s) are declared to be waste and are earmarked for disposal.

Utilities. Those services such as water, air, steam, sewage, telephone, and electricity necessary to the operation of an establishment.

Waiver. A documented authorization releasing a program or project from meeting a requirement after the requirement is put under configuration control at the level the requirement will be implemented.

4. GENERAL REQUIREMENT

4.1 Equivalency

Programs or projects may request to use systems, methods, devices, or measures of equivalent or superior quality, effectiveness, or safety in lieu of those prescribed by this standard. The ESO shall review for equivalency based on hazard analysis, technical documentation and may approve if there is no increased risk.

4.2 Process Safety Management

4.2.1 The program or project shall comply with 29 CFR 1910.119 for NASA explosive operations and energetic liquids which fall under the OSHA Process Safety Management requirements.

4.2.2 The ESO shall concur on the hazard assessment and controls to ensure compliance with 29 CFR 1910.119.

4.3 Audits

4.3.1 The ESO or knowledgeable designee shall conduct compliance audits to verify compliance with the requirements of this document and any Center document(s) specific to explosives storage, handling, transportation and operations.

4.3.2 Compliance audits shall be performed at least every two years but may be performed more often if deemed appropriate by the ESO.

4.3.3 The ESO shall produce a report of the audit findings. The Audit report should contain, as a minimum:

a. A list of the participants

b. The date(s) audit was conducted

c. The location of the audit

d. Scope of the audit

e. A description of the findings

4.3.4 Organizations being audited shall determine and document responses and corrections to the findings in accordance with NPD 8730.5. The ESO shall verify that the corrective actions resolving the findings have been implemented and the effectiveness of the actions have been verified .

4.3.5 Audit reports shall be retained by the ESO for a minimum of four years.

4.4 Minimum Use of Explosives

The quantity of explosives shall be the minimum required to carry out an operation in a safe and efficient manner.

4.5 Maximum Permitted Quantity of Explosives

The quantity of explosives shall not exceed the maximum permitted by the Quantity-Distance (QD) criteria or explosive facility license.

4.6 Operational Limits

Operational explosive materials limits shall be determined by the operating organization, but shall not exceed permitted quantities.

4.7 Personnel Limits

4.7.1 The number of personnel shall be the minimum consistent with safe and efficient operation.

4.7.2 In establishing personnel limits, the following principles apply:

a. Unrelated tasks shall not be performed concurrently during explosive operations.

b. Nonessential personnel shall not be allowed in the hazardous area during explosive operations.

c. Personnel limits shall allow for necessary supervision and transients.

d. Personnel shall use the buddy system (two persons) for all explosive operations.

4.8 Explosive Area Placarding

4.8.1 Maximum explosives and personnel limits for each explosives area (i.e. buildings, bays, rooms, test cells, and magazines) shall be documented.

4.8.2 A placard stating the maximum amount of explosives and the maximum number of personnel permitted in the explosive area at any one time shall be posted.

4.8.3 The placard shall be kept current and maintained for legibility.

4.9 Limit Review and Approvals

Changes (temporary or permanent) in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures by the ESO.

4.10 Access Controls

Access control shall be established to manage the presence of personnel in explosive areas.

4.11 Item Labeling

4.11.1 All inert explosives shall be marked, labeled, stenciled, or tagged as to their status.

4.11.2 Explosives not identified as inert shall be treated as live.

4.11.3 Various color coding schemes are utilized for identifying explosives (live or inert) throughout the explosives community. Center SOPs, operating procedures, drawings, or other pertinent records shall contain information pertaining to color-coding or other pertinent identifying labeling. A typical color scheme is blue for inert and red for live.

4.11.4 When components are transferred from one program to another, necessary changes in color coding shall be coordinated prior to the transfer.

4.12 ESO Responsibility

4.12.1 Explosives Safety Officer (ESO). A trained and experienced person shall be designated as the ESO at each NASA Center to manage the Center explosives safety program as specified in NPR 8715.1.

4.12.2 The ESO shall approve a training program for all explosive handlers. The training program serves to assist in conducting work safely and developing safety awareness.

4.12.3 The ESO shall be responsible for ensuring the certification process of explosive handlers. Certification may be performed by the ESO, certifying board or other means deemed appropriate by the ESO.

4.12.4 The ESO shall have the authority to revoke an individual's explosive handler's certification.

4.12.5 The ESO shall verify and document that off-site personnel coming on site to perform temporary explosives work have met an equivalent explosives training program prior to work being performed on site. Documentation should include, at a minimum a list of training classes and on-the-job training completed.

4.13 Supervisory Responsibility

4.13.1 The supervisor shall be responsible for the following:

a. Providing classroom and on-the-job training for the explosives handlers.

b. Verifying that the explosives handlers are qualified and able to safely perform the work and have met all the class training and on-the-job training requirements.

c. Ensuring that the explosives handlers meet the medical examination requirements of NPR 1800.1 with an initial and then biennial medical examinations.

4.13.2 The supervisor shall have the authority to revoke an individual's explosive handler's certification.

4.13.3 The supervisor shall maintain records for each explosives handler that includes:

a. Description and date of training (retraining, when required) received

b. Description and date of certification (recertification, when required) received

c. Date of medical examination completion

4.13.4 The supervisor shall not permit an explosives handler to continue working with explosives if the supervisor, with counsel from medical personnel as necessary, determines that the person is unable to perform the task safely. Possible reasons include but are not limited to the following:

a. Physical injury, illness, drug test results or disease

b. Mental or emotional disturbances

c. Loss of driving privileges (state or center)

4.14 Explosives Handler Responsibility

4.14.1 The explosive handler shall:

a. Work with explosive systems on which they are certified.

b. Complete training requirements.

c. Self-report any issues that may affect health or driving privileges.

d. Report any operational or training issues that may affect safe operations.

e. Use personal protective equipment (PPE).

f. Maintain certifications including periodic recertification training.

g. Complete and pass an initial and then biennial medical examinations in accordance with NPR 1800.1.

4.15 ESO and Explosives Handlers Training and Qualifications

4.15.1 Explosives handlers shall be properly trained before assignment to any explosives operation or operating any explosives-carrying vehicle.

4.15.2 Each organization shall designate a certifying official and have a training certification program approved by the ESO.

4.15.3 The training shall include instructor-led, hands-on training on how to safely handle explosives, followed by satisfactory on-the-job performance as a trainee.

4.15.4 The training program shall include the following:

a. The importance of a safe attitude toward work with explosives.

b. The potential hazards and risks involved.

c. The correct skills and procedures for safe performance of the task.

d. Unexpected hazardous conditions and emergency situations to include electrical storms.

e. The appropriate operating procedures.

f. Information on physical and health hazards.

g. The purpose and proper use of engineering controls, work practice controls, and PPE.

h. Labeling systems and Safety Data Sheet terms.

i. Detection methods for the presence or release of a hazardous material in work areas.

j. Hazard Classification.

k. Storage Compatibility, placards and symbols.

4.15.5 The training shall include a recurring training process to ensure explosives handlers retain their qualifications.

4.15.6 All explosives handlers shall complete a basic explosives safety certification program. The certification shall be valid for a specific period of time not to exceed three years.

4.15.7 Explosives handlers shall be recertified at the end of the three-year period.

4.15.8 Explosives handlers who do not demonstrate job proficiency or who violate safe practices shall be retrained in the specific area of weakness or have their certifications terminated.

4.15.9 The ESO shall have a minimum of 40 hours of continuing education (every 2 years) which will consist of a minimum of 16 hours required in the explosives discipline.

Note: A maximum of 24 hours teaching an explosives realated class or attendance at a explosives related conference/Working Group count towards this requirement.

4.15.10 The ESO and the explosives handlers shall at a minimum, meet the training expectations found in Appendix C.

Note: It is expected that Centers will develop unique individual training plans which utilize a number of different training sources to include those found within and outside NASA in support of their unique requirements.

4.16 Preparing and Controlling Procedures for Explosives Operations

4.16.1 This section establishes requirements for preparing and controlling all procedures involving explosives operations.

4.16.2 Before initiation of any explosives operations, operating procedures shall be written by the responsible organization and approved/concurred by the ESO.

4.16.3 Supervisory personnel shall be responsible for enforcing provisions of all procedures.

4.16.4 Procedures and technical changes to procedures shall be prepared by responsible personnel with knowledge of the explosives operations involved.

4.16.5 Operational steps presented in the procedure shall be checked for compliance with the standards of this document and other relevant documents.

4.16.6 Each employee involved in an explosives operation shall have stop work authority.

4.17 Explosives Operating Procedures

4.17.1 Distribution of procedures shall be controlled to ensure that the most current revision is used.

4.17.2 Revised operating procedures shall be reviewed and approved/concurred by the ESO prior to use.

4.17.3 Reactivated or new procedures shall have a tabletop/dry run prior to submission for approval.

4.18 Facility Construction

4.18.1 The ESO shall review and approve facility construction for explosive storage and operations, as well as construction and modification of facilities affected by explosives storage and operations.

4.18.2 Operational shields shall be designed to provide protection to personnel, material, or equipment from the effects of a possible fire or explosion and in accordance with MIL-STD-398.

4.18.3 Blast doors that impede exit from the facility shall not be used on outside exits in place of emergency exits.

4.18.4 Natural and artificial barricades shall be designed and used in accordance with Department of Defense Explosives Safety Board (DDESB) Technical Paper 15 (TP15).

4.18.5 The earth cover between Earth-covered Magazines (ECMs) may be either solid or sloped, but a minimum of 2 feet of earth cover shall be maintained over the top of each magazine. If the specified thickness and slope of earth on magazines, are not maintained, the magazine shall be repaired as soon as practical (not to exceed 90 days) or classified as an aboveground magazine.

4.18.6 Certain ECM, aboveground magazines, and containers have been approved with reduced Net Explosive Weight (NEW) and/or reduced QD, and are listed in DDESB TP15. The use and siting of these structures and containers shall meet all conditions/restrictions specified in the design and approval documentation, as described in DDESB TP15.

4.19 Explosives Site Plans and Explosives Facility Licenses

4.19.1 Explosives site plans or explosives facility licenses shall be required for all explosives areas. Appendix A provides general guidance on content to be covered in the explosives site plan.

4.19.2 The ESO shall review and approve explosives site plans and explosives facility licenses for explosives storage and operations.

4.19.3 Explosives Site Plan

4.19.3.1 An explosives site plan shall show protection provided against explosion propagation. Guidance for developing an explosives site plan is provided in Appendix A.

4.19.3.2 Atmospheric dispersion of flammable and/or toxic vapors should be considered in the explosives site plan.

4.19.3.3 The explosives site plan or facility license for static test stands shall address over-pressurization for solid motor test operations.

4.19.3.4 Inventory of stored explosives material shall be reported to the ESO no less than annually. At minimum the explosives inventory report will include description, quantity, location, net explosives weight, hazard division classification, lot number and or serial number.

4.19.4 Licensed Explosives Locations

4.19.4.1 Licensed explosives locations are intended to provide short term storage or operational capabilities for small quantities of explosive materials and devices which are normally outside the Center's primary explosives storage area(s).

4.19.4.2 Organizations shall request a license to be issued by the Center's ESO.

4.19.4.3 The explosives facility license (NASA Form (NF) 1791 or equivalent) shall be issued annually.

4.19.4.4 Each license shall be signed by the requesting organization and submitted, in accordance with the Center's policies and procedures, for concurrence or approval to the local explosives storage facility operating organization, the local protective services office, and/or the local fire protection agency, as applicable, prior to being approved by the ESO.

4.19.4.5 A copy of the license shall be posted at the licensed explosives location and retained for 2 years.

4.19.4.6 Licensed compatibility groups shall not include groups A, K, and L.

4.19.4.7 Small arms ammunition may be stored in a safe meeting the requirements of Federal Specification AA-F-358, Filing Cabinet, Legal and Letter, Size, Uninsulated, Security, Class 5 or Class 6 or other container/vault that meets security requirements.

4.19.4.8 A minimum separation distance of 25 feet is required between licensed explosives locations containing Hazard Division (HD) 1.3 explosives and adjacent explosives operations, personnel, or other licensed locations containing HD 1.3. Where 25 feet cannot be obtained, a 2-hour firewall, constructed in accordance with NFPA 221, shall be provided.

4.19.4.9 The structure or room used to store explosives shall be locked when not occupied.

4.19.4.10 Appropriate fire/chemical warning signs or DOT placards shall be posted when explosives are present. Security and other law enforcement services may be exempted from this requirement provided the following conditions are met: (1) storage is in a Class 6 safe in accordance with General Services Administration (GSA) Federal Specification AA-358, (2) quantities of material are reported to the ESO no less than annually, and (3) concurrence of the ESO and local fire department are obtained.

4.19.4.11 Safety Requirements for Specific Facilities and Explosives

4.19.4.11.1 Armories and weapons issue points shall comply with the licensed explosives location requirements except in locations used exclusively for the storage and/or distribution of small arms ammunition. The accountability, storage, control, and issuance of small ammunition at these locations shall be the responsibility of the Center Protective Services in accordance with NPR 1600.1.

4.19.4.11.2 An explosives facility license shall be required for those areas in which survival equipment explosive components are stored. An explosives facility license is

not required for assembled parachutes, survival and rescue kits, life rafts and life preservers containing authorized explosives when kept in personnel equipment rooms or life raft, survival equipment, and life support shops.

4.19.4.11.3 When necessary, the ESO may license a limited quantity of in-use egress explosive components of any class/division (excluding HD 1.1/1.2) in the egress shop after removal from aircraft undergoing maintenance. Do not exceed the total number of complete sets for the number of aircraft in maintenance. The following special provisions apply:

a. Ejection seats and canopies with explosives components not undergoing actual maintenance shall be stored in a location separate from the maintenance area.

b. Unserviceable or expended explosives materials and devices shall be managed in accordance with the Center's procedures for unserviceable or expended materials.

4.19.4.11.4 Explosives storage locations for gun and skeet clubs that operate on NASA property shall be licensed.

4.19.4.11.5 Morale, Welfare, and Recreation (MWR) activities such as aero clubs and boating activities may be required to maintain and store commercial pyrotechnic signals. These items shall be controlled and stored in accordance with the requirements of this document.

4.19.4.11.6 Explosives used for laboratory research/testing project shall be licensed only for the length of the project.

4.20 Explosives Waste Requirements

The transportation, storage, treatment, and disposal of explosives wastes shall comply with DOT, Environmental Protection Agency (EPA), state, local, and NASA regulations or requirements regarding hazardous wastes, including any site-specific permits, waivers, or interpretations. Assistance and coordination regarding hazardous waste requirements should be obtained through the local Center's environmental management office.

4.21 Law Enforcement

Organizations having authority to obtain, use, and maintain arms, ammunition and explosives shall comply with the requirements of this document and with the current NASA security requirements established in NPR 1600.1. These minimum requirements ensure the appropriate level of protection and serve to deny access to unauthorized personnel.

5. DETAILED REQUIREMENTS

5.1 General

This chapter establishes standard firefighting hazard identification and measures for fighting fires of explosives. To provide a guide for firefighting forces, these explosively hazardous fires are divided into four fire divisions identified by the numerals 1, 2, 3, and 4. Firefighting procedures, training of firefighting personnel, use and maintenance of firefighting equipment

and vehicles, provision of water supply and alarm system, first aid measures, and other measures required in firefighting are covered in NASA-STD-8719.11.

5.2 Fire Protection Criteria

A minimum of two serviceable fire extinguishers, suitable for the hazards involved, shall be provided for immediate use at any location where explosives are being handled.

5.3 Display of Fire, Chemical and/or Apply No Water Symbols

5.3.1 NASA Centers and Component Facilities are served by resident, civilian and/or military fire departments. Depending on the fire department type, at least one of four standards of explosives symbols are recognized. The standards originate from DoD, DOT, and NFPA.

5.3.2 When explosives are present, applicable placard(s) shall be displayed on the exterior of all explosives areas to visually inform emergency responders. Each symbol shall comply with its governing standard:

5.3.2.1 DoD 6055.09 Fire Division Symbols

5.3.2.2 DoD 6055.09 Chemical Hazard Symbols

5.3.2.3 DOT, 49 CFR, Part 172, Subpart F, “Placarding”

5.3.2.4 NFPA 495, Explosives Materials Code

5.3.3 An uniform standard shall be chosen to be displayed on the exterior of explosives facilities throughout the center. Multiple standards may be employed if required due to first responder requirements.

5.3.4 The symbol(s) shall be displayed so the alpha-numerical value is in a vertical position and is easily visible for the greatest distance from each approach route of emergency responders.

5.3.5 When explosives are present, applicable placards (see 5.3.2) shall be displayed at the interior entrance of explosives areas. The placards shall be no smaller than six inches.

5.3.6 Ready storage boxes, safes or other appropriate containers shall be marked with the appropriate symbol when explosives are stored.

5.3.7 The symbol displayed shall reflect the most hazardous explosives material stored in the area. For long dimensional buildings with access from several directions, more than one symbol to a side may be necessary.

5.3.8 Facility warehouses and storage facilities used for storage of containers from which explosives have been removed, but which have not been decontaminated to remove explosive residue, shall be identified with the appropriate symbol(s) consistent with the degree of hazard.

5.3.9 Coordination and training for local jurisdictions may be required in order to ensure that emergency responders are aware of their use of fire symbols. This should be provided for in pre-fire planning and communication.

5.3.10 When security or other considerations make it undesirable to identify explosives with symbols at the actual location, the ESO can eliminate this requirement for exterior location(s) with Center Director approval. A pre-fire plan and communications between emergency responders shall be established.

5.3.11 In lieu of posting every storage structure, the ESO may designate blocks or a single row of storage sites, above ground magazines, or earth-covered magazines as areas requiring posting for the most hazardous material. The symbols shall be located at the entrance to the block or row and shall be clearly visible to approaching emergency responders.

5.3.12 A master list of all explosives areas and their locations, and empty storage sites shall be made available to the local (i.e. responsible) fire and security office and ensure the information is dispatched to the responders.

5.3.13 Motor vehicle and railroad car placards shall be displayed in accordance with 49 CFR, Part 172, Subpart F, “Placarding”.

5.4 Vegetation Control

5.4.1 Vegetation around storage magazines, explosives operating facilities, test stands, and test areas shall be controlled to minimize potential damage to the magazine or facility from grass, brush, forest fires, or erosion.

5.4.2 A firebreak at least 50 feet wide and free from combustible material should be maintained around storage magazines, explosives operating facilities, test stands, and test areas.

5.4.3 If the aboveground magazine or explosives facility exterior is fire resistant, the firebreak need not be devoid of vegetation, but growth shall be maintained to prevent rapid transmission of fire to the magazine or facility.

5.4.4 Maintenance of firebreaks and cutting of vegetation around earth-covered magazines are not normally required. Vegetation around ventilators shall be maintained to prevent transmission of a fire into a structure.

5.5 Motor Vehicle Safety Requirements

5.5.1 Automobiles shall be restricted to only parking in designated areas.

5.5.2 Government owned vehicles (GOV), motorized ground support equipment (GSE), and privately operated vehicles (POV) parking areas shall be located a minimum of 100 feet from explosives processing areas. The ESO may modify these parking requirements with a documented assessment.

5.5.3 Temporary parking of GOVs and GSE, other than for loading or unloading, shall not be closer than 25 feet from explosives processing areas. The ESO may modify these parking requirements.

5.5.4 Parking of POVs shall be controlled to minimize fire and explosives hazards and prevent congestion in the event of emergency. POVs should not be parked close enough to a building to either enable the spread of fire from an automobile to the building or hinder access by emergency responders.

5.6 Grounding and Bonding

5.6.1 Grounding is the process of bonding one or more conductive objects to the ground, so that all objects are at zero (0) electrical potential. Bonding is the process of controlling static electric hazards by connecting two or more conductive objects together by means of a conductor so that they are at the same electrical potential, but not necessarily at the same potential as the earth.

5.6.2 All grounds shall have a resistance of 25 ohms or less.

5.6.3 The grounding system shall be visually inspected every six months.

5.6.4 The grounding system shall be tested at a minimum, annually and following any lightning strikes.

5.6.5 The grounding system test results shall be documented and retained for a minimum of 3 years.

5.6.6 Ground conductors shall be visually inspected before each day's operation.

5.6.7 Bonding straps shall be used to bridge locations where electrical continuity may be broken by oil on bearings, paint, or rust at any contact point.

5.6.8 Power and communication lines shall enter the facility in shielded cables or in metallic conduits buried underground for at least 50 ft. from the structures.

5.6.9 Intrusion detection systems, utilities lines (such as water, steam, and air conditioning), and other metallic lines shall be buried underground for at least 50 ft. from the structure.

5.6.10 Protection from the hazards of lightning discharges shall meet the following:

5.6.10.1 Re-verify the connection, when disconnected from a ground.

5.6.10.2 Test methods for performing continuity tests of the ground cable incorporate connecting the leads from an ohmmeter or equivalent to the ends of the ground cable.

5.6.10.3 Ensure the size of the ground cable is sufficient to prevent the wire from breaking during the worst case conditions under which it will be used.

5.6.10.4 Ensure the connectors on ground cables are not insulated.

5.6.10.5 Ensure a permanent, visible ground is connected. Permanent equipment in contact with conductive floors or table tops is not considered to be adequately grounded. Dual ground paths are recommended.

5.6.10.6 Ensure static grounds are not made to gas, steam, or air lines, dry pipe sprinkler systems, or air terminals of lightning protection systems.

5.6.10.7 When applicable, attach the ground cable to the explosives/propellant container (e.g., rocket motor case) first and then to building/facility ground.

5.6.10.8 Static grounds can be made to conductive water pipes that have been tested and verified to be permanent and continuous, ground cones, buried copper plates, driven ground rods, or to down conductors of lightning protection systems as close to the ground rod or counterpoise as possible.

5.6.10.9 Ensure bonding wires/cables and ground wire have adequate capacity to carry the largest currents that are anticipated (see the National Electrical Code (NEC)).

5.6.10.10 Utilize flexible conductors for bonds that are frequently connected and disconnected.

5.6.10.11 All grounding mediums, including equipment grounding and bonding systems and lightning protection, should be bonded together as close to the grounding rod or counterpoise as possible.

5.6.11 Facility ground shall be verified to ensure an electrical continuity test has been conducted before bonding to facility ground.

5.7 Lightning Protection

5.7.1 NASA facilities involved in the development, manufacturing, testing, handling, storage, maintenance, and disposal of explosives shall comply with the requirements of NFPA 780 and the NEC regarding the design of LPSs.

5.7.2 Wires and connectors on LPS shall not be painted or concealed (sheathing removed).

5.7.3 Fences shall have bonds across gates and be bonded to the LPS, if they come within 6 feet of the system.

5.7.4 The resistance of any metal object bonded to the LPS shall measure 1ohm or less.

5.7.5 A LPS shall be required for explosives facilities unless one of the following conditions are met:

a. A lightning warning system is available to permit termination of operations and withdrawal of all personnel to Inhabited Building Distance (IBD) prior to an electrical storm.

b. ECMs do not require a LPS. However, if the ECM has a conductive structure such as a ventilator or air conditioning unit a LPS may be required.

c. Facilities contain explosives that cannot be initiated by lightning as determined by test and analysis performed by the requesting organization and approved by the ESO.

5.7.6 Minimum LPS Testing and Inspection.

5.7.6.1 LPS shall be visually inspected once every six months.

5.7.6.2 LPS shall be electrically tested annually.

5.7.6.3 LPS testing results shall be documented and retained for a minimum of 3 years.

5.8 Explosives in Process during Electrical Storms

5.8.1 Upon notification of an approaching electrical storm within 10 miles, personnel shall begin shutdown of explosives operations and evacuation of the explosives areas.

5.8.2 Personnel shall be evacuated to a suitable area that will provide protection.

5.9 Static Electricity and Control of ESD

5.9.1 This section covers methods for the prevention of accumulation of static electricity for the purpose of eliminating or mitigating ESD. The generation of static electricity is not in itself a hazard. The hazard arises when static is allowed to accumulate, subsequently discharging as a spark across an air gap in the presence of highly flammable materials or energetic materials such as explosives.

5.9.2 Personnel Electrostatic Discharge Equipment and Conductive Floors

5.9.2.1 Approved static dissipation equipment shall be used in explosives operations.

5.9.2.2 Personnel wearing leg stats, one on each leg, shall stand on a grounded conductive surface.

5.9.2.3 Personnel wearing wrist straps shall connect the lead clip to a facility/vehicle ground.

5.9.2.4 Personnel beginning operations in an ESD sensitive area shall check all personnel grounding devices for proper resistance using a calibrated ohmmeter or certified tester prior to beginning operations.

5.9.2.5 When wearing leg stats, the resistance between the wearer and facility ground shall measure 25,000 ohms minimum to 1 megohm maximum.

5.9.2.6 A certified tester or ohmmeter shall be used to verify that the resistance between the wrist strap and opposite hand is between 1megohm minimum and 10 megohms maximum.

5.9.2.7 Upon each connection to facility ground, the bond shall be tested (resistance).

5.9.2.8 A retest shall be made if the bonding device is removed.

5.9.3 In explosives operations, steps shall to be taken to control ESD. Some common practices of control and/or reduction of explosives hazards from ESD are as follows:

a. Relative humidity (RH) in the operational area shall be determined and recorded prior to the start and every 4 hours during operations involving open rocket propellant grains, rocket motors with nonconductive cases, open flammable/combustible fluid systems, and explosives trains.

b. For conditions at or below 50% RH:

(1) Bonding, grounding, nonconductive materials, and personnel grounding devices shall be verified at less than 350 volts potential.

(2) Electrostatic scanning of personnel, materials, and hardware within ten feet of the operation, not to exceed 1-hour intervals, shall be performed during the operation and at any time additional personnel, equipment, or hardware are introduced into the immediate area, the RH goes lower, or the handling of nonconductive materials is required.

(3) Continuous RH monitoring shall be performed.

(4) When operations are permitted at 30% RH or below, electrostatic scanning shall be accomplished at 10-minute intervals if the explosives material is exposed and 30-minute intervals if the explosives material is covered.

(5) The maximum voltage potential shall be dependent upon the explosives material sensitivity to ESD.

c. Ionization methods of removing static charges shall not be used in hazardous locations as defined in the NEC unless approved specifically by the ESO. Ionization serves as an effective method for removing static charges from certain processes and/or operations.

d. Cold temperatures can contribute to dielectric breakdown of propellants, which could make a propellant more susceptible to ignition by ESD.

e. Minimize surface area contact to minimize triboelectrification.

f. Where possible, static dissipative materials/coatings should be provided that will not allow point-discharging and/or will slowly bleed off any accumulated charges in a manner that will reduce the buildup of sufficient charge for ESD spark discharge.

g. Use precautions when working around liquid oxygen, since oxygen gas may permeate clothing and a static discharge could result in ignition.

h. Use caution in design and selection of packaging materials, and support equipment.

i. Prohibit use of static or electromagnetic field generators or materials in the area.

j. Use inert gases for ullage space.

k. Composites shall have a surface resistivity less than 10^9 ohms per square.
(Note: size of the square is unimportant)

l. Use anti-static spray, if approved by the ESO and hardware owner.

m. The “First Touch Rule” considers a handler is electrically charged. As such, the handler must consider where the discharge is going to take place by considering their “first touch”. A handler should always avoid making the “first touch” or connection to the explosive device first. The handler should seek the same potential by touching a grounded device at the same potential which is not directly in contact with the explosive device prior to handling any explosive device.

5.10 Laboratory Testing of Explosives Safety

5.10.1 Explosives, quantities of explosives synthesized, and characterization of explosives in the laboratory will be in accordance with the laboratory chemical hygiene plan.

5.10.2 ESO may license small quantities of explosives materials for research/testing in laboratories. A maximum of 200 grams of TNT equivalent explosives material is recommended.

5.10.3 Laboratory work involving explosives materials shall be performed in accordance with written operating procedures.

5.10.4 The quantity of explosives present in the laboratory shall be the minimum required for the operations.

5.10.5 Open flames shall be prohibited in laboratories where explosives or flammable solvent vapors are present, unless allowed by approved hazards assessment and procedure.

5.10.6 Safety Shields.

5.10.6.1 If a laboratory operation involves an explosion hazard, personnel shall be protected by safety shields or the operation be performed by remote control. Table 5-1 lists shields that have been tested and found acceptable for the indicated quantities of explosives.

Table 5-1. Safety Shields for Explosives Laboratory Operations

Shield	Minimum distance from explosives	Explosives limit
	(in)	**(oz)**
	[cm]	**[g]**
Leather gloves, jackets, or coats and plastic face shields	----	.77(grains)
		.05
1/8” (3 mm) tempered glass	3.15	.77(grains)
	8	.05
¼” (7 mm) Lucite®/equivalent material	5.91	.0882
	15	2.5
3/4” (20mm) Lucite®/equivalent material	5.91	.3527
	15	10
5/8” (15mm) Laminated resistant glass	7.874	.7054
	20	20
1” (25.4) Lexan™/Lexguard®	11.81	1.764
	30	50
2 units each of 1” (25.4) plate glass laminated with ½” (12.4 mm) polycarbonate with a 3/8” (9.5mm) air gap between units (glass sides facing the explosives)	11.81	1.764 (steel confined)
	30	50 (steel confined)

(Reference: DOE-STD-1212-2012, June 2012)

NOTE: Recent blast testing has shown that laminated tempered glass is superior to monolithic tempered glass, and polycarbonate is superior to acrylic plastics, such as Lucite®. Laminated tempered glass is recommended instead of monolithic tempered glass and polycarbonate is recommended in lieu of acrylic. The shields are recommended to be of equal or greater thickness than those listed in the table. Proof testing is highly recommended. When designing and/or replacing a safety shield with a polycarbonate, it should be UV stabilized, treated for abrasion resistance, and have met A-A-59502. When designing or replacing a safety shield with laminated glass, it should be coated with a .003937 in (0.1 mm) fragment-resistant film on the viewer's side to minimize spalling. The shield, shield frame, and anchoring system shall be designed to resist maximum credible overpressure and fragments.

NOTE: Shields listed in this Table 5-1 were not tested for metal-fragment penetration (unless specifically indicated) and thus may not offer effective protection when the explosive is closely confined in a heavy-walled metal container. ("Heavy-walled" is defined here as wall thickness to diameter ratio greater than 0.01.)

5.10.6.2 If an experiment presents a metal-fragment hazard (as opposed to a glass-fragment) and cannot be conducted remotely, the proposed shield shall be tested and approved under conditions simulating an explosion in the experimental setup but with at least 125% of the anticipated explosives content.

5.10.6.3 The shield shall be anchored to the hood frame or bench top.

5.10.6.4 Other shields may be used after successfully passing a test of 125% of the rated explosives charge and being approved.

5.10.6.5 For confined areas, a blast vent having less strength than the shield shall be provided.

5.10.7 Explosives Heating Operations in Laboratories

5.10.7.1 Heat shall be applied indirectly using steam, a water bath, oil bath, or an approved laboratory electrical heating device.

5.10.7.2 Utmost caution shall be exercised to ensure that reactive material does not come in direct contact with the heating elements.

5.10.7.3 Heating devices shall be equipped with a temperature controller or temperature sensing device that will turn off the electric power, if the temperature device exceeds preset limit.

5.10.7.4 If an experiment must be conducted behind a shield, any heating device shall be mounted so that temperature can be controlled from the operator side of the shield.

5.10.7.5 The heating device shall incorporate a system that can be quickly separated from the reaction vessel or power removed without operator exposure. During design of the experiment, consideration should be given to providing emergency cooling for the reaction vessel or its contents.

5.10.7.6 Heating of explosives with devices not incorporating the safety features shall be monitored at all times and the heating device turned off if the operator must leave for any reason.

5.10.7.7 Direct heating of test articles (explosives) where the purpose is to cause intentional decomposition or combustion shall be permitted with adequate safety controls.

5.10.7.8 Heating systems that will be operated unattended shall have dual controls, an override shutoff, or some other protection against failure of the primary heating control. Systems capable of total containment of the effects of an explosion may be exempted from this requirement.

5.10.7.9 In the case of remotely controlled operations, provisions shall be made for observations using equipment such as mirrors, television monitors, or similar devices.

5.10.8 Low Concentration of Explosives in Solution

5.10.8.1 When explosives are in a dilute solution (less than 25% explosives by weight), the primary hazard shall be considered as that associated with the solvent and not the explosive.

5.10.8.2 The safety guidelines for pure explosives shall apply until explosives are in solution, or if for any reason the explosives recrystallizes or precipitates out of solution.

5.10.9 Time Sensitive, Shock Sensitive, Peroxide Forming Chemical Management and Compatible Storage

5.10.9.1 A wide variety of organic compounds spontaneously form peroxides by a free-radical reaction with molecular oxygen in a process of auto-oxidation.

5.10.9.2 Table 5-2 lists moieties that are most likely to form peroxides.

Table 5-2. Moieties That Can Form Organic Peroxides

1. Ethers and acetals w/α- hydrogen	6. Vinyl alkynes w/α- hydrogen	11. Secondary Alcohols
2. Alkenes w/alyllic hydrogen	7. Alkylalkynes w/α-hydrogen	12. Ketones w/α-hydrogen
3. Chloroalkenes, fluoroalkenes	8. Alkylalkynes w/tertiary α-hydrogen	13. Aldehydes
4. Vinyl halides, esters, ethers	9. Alkanes and cycloalkanes w/tertiary hydrogen	14. Ureas, amides, and lactams w/α-hydrogen atom on a carbon attached to nitrogen
5. Dienes	10. Acrylates, methacrylates	

(Reference: Management Procedures for Organic Peroxide Forming Chemicals and other Explosive Chemicals, NMSU, September 2014)

NOTE: These moieties are ranked from highest (1) to lowest (14) risk of forming potentially dangerous peroxide concentrations.

5.10.9.3 Peroxides may explode when concentrated by evaporation or distillation, combined with compounds that create detonable mixture, or when disturbed by heat, shock, or friction.

5.10.9.4 Peroxide safety management guidelines include:

a. Any peroxidizable chemical with visible discoloration, crystallization, or liquid stratification shall be treated as potentially explosive. Call the appropriate Center environmental or safety, and health office and the ESO for immediate assistance.

b. All containers of peroxide-forming chemicals shall be labelled with the date the chemical was received and the date the container was opened (See Figure 5-3 for example of label).

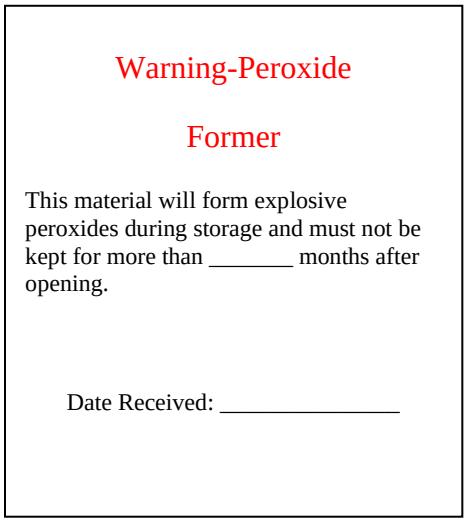

Figure 5-1. Sample Label

c. Peroxide-forming chemicals shall not be distilled to dryness unless tested negative for peroxides.

d. Compounds listed in Tables 5-3, 5-4, and 5-5 shall be tested for peroxides prior to distillation, evaporation, or turned in as waste.

5.10.9.5 Table 5-3 lists chemicals that form potentially explosives peroxides without concentration.

Table 5-3. Chemicals That Form Potentially Explosives Peroxides Without Concentration[a]

Butadiene[b]	Potassium amide[c]
Chloroprene[b]	Sodium amide[c]
Diisopropyl ether	Sodamide[c]
Divinyl acetylene	Tetrafluoroethylene[b]
Divinyl ether	Vinylidene chloride
Isopropyl ether	

(Reference: Management Procedures for Organic Peroxide Forming Chemicals and other Explosive Chemicals, NMSU, September 2014)

NOTES:
[a] Materials other than those listed may form peroxides. These chemicals can be a particular hazard since peroxides can form even without opening the containers. Therefore, only small amounts should be ordered and used as soon as possible. After opening, they should not be kept

for over three months. When possible, store these chemicals under a nitrogen blanket. Review the references and contact your Industrial Hygienist office for further information.
[b] When stored as a liquid monomer.
[c] Inorganic Peroxide Former.

5.10.9.5.1 Materials may spontaneously form peroxides that will make the material shock- or heat-sensitive "on the shelf", that is, without any further concentrations through evaporation or distillation. A three-month storage limit shall be imposed on the materials and they shall be stored under nitrogen, if practical.

5.10.9.6 Table 5-4 lists chemicals that form potentially explosive peroxides on concentration. After opening, they shall not be kept for over 12 months

Table 5-4. Chemicals That Form Potentially Explosive Peroxides on Concentration [a, b]

Acetal	Ethylene glycol dimethyl ether
Acetaldehyde	Ethylene glycol ether acetates
Benzyl alcohol	Furan
Butadiyne	Glyme
2-Butanol	4-Heptanol
Cellosolves	2-Hexanol
Chlorofluoroethylene	Isopropyl alcohol
Cumene	Isopropylbenzene
Cyclohexene	Methyl acetylene
Cyclohexanol	3-Methyl-1-butanol
2-Cyclohexen-1-ol	Methyl cyclopentane
Cyclooctene	Methyl isobutyl ketone
Cyclopentene	4-Methyl-2-Pentanol
Decahydronaphthalene	4-Methyl-2-Pentanone
Decalin	2-Pentanol
Diacetylene	4-Penten-1-ol
Dicyclopentadiene	1-Phenylethanol and 2-Phenylethanol
Diethyl ether	2-Propanol
Diethylene glycol	Tetrahydrofuran
Diglyme (Dimethyl ether)	Tetrahydronaphthalene
Dioxanes	Tetralin
Ethyl ether	Vinyl ethers

(Reference: Management Procedures for Organic Peroxide Forming Chemicals and other Explosive Chemicals, NMSU, September 2014)

NOTES:
[a] Materials other than those listed may form peroxides. Review the references and contact your Industrial Hygienist for further information.
[b] Warning! These chemicals typically accumulate hazardous levels of peroxides when evaporated, distilled, contaminated, or have their peroxide inhibiting compounds compromised.

5.10.9.7 Table 5-5 lists chemicals that autopolymerize.

a. These chemicals may autopolymerize (and thus explode) when relatively small quantities of peroxides are formed.

b. Uninhibited chemicals shall be stored for ≤ 2 days.

c. When inhibited, chemicals shall be stored no longer than 12 months.

Table 5-5. Chemicals That Autopolymerize [a]

Acrylic acid	Indene
Acrylonitrile	Methyl methacrylate
Butadiene[b]	Styrene
Chlorobutadiene	Tetrafluoroethylene
Chloroprene	Vinyl acetate
Chlorotrifluoroethylene	Vinyl acetylene
Dibenzocyclopentadiene	Vinyl chloride
9,10-Dihydroanthracene	Vinyl pyridine

(Reference: Management Procedures for Organic Peroxide Forming Chemicals and other Explosive Chemicals, NMSU, September 2014)

NOTES:
[a] Materials other than those listed may form peroxides. Review the references and contact your Industrial Hygienist for further information.
[b] When stored as a gas.

5.11 Concurrent Explosives Operations

5.11.1 Concurrent explosives operations are discouraged within the same explosives area. Concurrent explosives operations in the same explosives area shall require an operational layout and plan to segregate the primary hazards by dividing walls, barricades, or other means to ensure maximum personnel protection.

5.11.2 If concurrent explosives operational necessity arises, a hazard assessment shall be performed and hazard controls implemented to ensure the safety of operations and personnel, including personnel emergency egress.

5.11.3 Segregation plans and operational procedures shall be approved by the ESO.

5.12 Physical Security Requirements

5.12.1 Magazines, permanent day boxes, and rooms shall be locked with a high security lock, and where appropriate, a high security hasp. Where two hasps are present two locks shall be used. Where one hasp is present it is encouraged to establish a second hasp.

5.12.2 Magazines, permanent day boxes and rooms shall have an in/out entry log. The entry log shall be retained by those responsible for the magazine, permanent day box or room for a minimum of one year.

5.12.3 Key and lock control procedures shall be established and approved for all magazines, permanent day boxes, and rooms that contain explosives by the ESO.

5.12.3.1 Use of a master key shall be prohibited, unless required by emergency responders.

5.12.3.2 A key sign out/in log sheet shall be implemented. The log sheet is to be retained by those responsible for the magazine, permanent day box or room for a minimum of one year.

5.12.4 Empty magazines, permanent day boxes, and rooms shall be locked to prevent inadvertent placement of explosives materials.

5.12.5 A security cage should be considered for a license location not in the open, i.e., inside the building or room.

5.12.6 Use of an Intrusion Detection System (IDS) should be considered. Signs clearly announcing the presence of an IDS should be displayed on ammunition storage rooms, magazines, or perimeter barriers (security fencing) using such system. Signs should be affixed at eye level, when possible.

5.12.7 When present, IDS signs should be affixed on the exterior walls containing an entrance to the ammunition or explosives storage room, vault, building, or magazine in the case of an alarmed barrier fence, on the outside of the fence at about 100 yard intervals.

5.12.8 Perimeter security fencing should be established for potential explosives site (PES).

5.12.9 Perimeter security fencing should be established for remote licensed locations. Examples are a magazine at a firing range or a magazine offset from the test facility housing explosives materials supporting the test facility in which the magazines are in the open or offsite locations.

5.12.10 Vehicle and personnel gates shall be secured at all times when no one is present. Gates should remain closed but may remain unlocked to allow authorized entry into or exit from the area when personnel are present.

5.12.11 Consider using, floodlights, alarms (in addition to IDS), security cameras, or other security devices at magazines and PESs to better monitor the location.

5.12.11.1 Post alarm-monitoring signs in highly visible places to deter unauthorized access.

5.12.12 Facilities housing explosives (the outer most locked entrance(s)) shall be checked by a security patrol daily. The following locations shall be exempt the security patrol:

5.12.12.1.1 The following locations shall be exempt the security patrol:

5.12.12.1.1.1 Facilities protected by guarded surveillance.

5.12.12.1.1.2 Facilities protected by an IDS which reports to a manned (24/7) central location from which a response force can be dispatched.

5.12.12.1.1.3 Facilities with a security risk assessment and security plan that have been approved by both NASA security and the ESO.

5.12.13 Any person who has knowledge of the theft or loss of any explosive materials shall report such theft or loss immediately to Security and the ESO. ESO shall inform the Center Director and NASA Headquarters Explosives Safety Manager (ESM).

5.13 Housekeeping

5.13.1 Structures containing explosives shall be kept clean and orderly.

5.13.2 General cleaning shall not be conducted while hazardous operations are being performed. Explosives should be removed from the area prior to general cleaning operations.

5.13.3 The accumulation of explosives shall be prohibited.

5.13.4 Waste materials such as oily rags; hazardous waste such as combustible and explosives scrap; and wood, paper, and flammable packing materials shall not be mixed, but be kept separately in carefully controlled, approved, and properly marked containers.

5.13.5 Containers shall be kept outside explosives facilities, except for containers that are required at workstations, and be emptied at least once each workday or shift.

5.13.6 Containers for hazardous waste shall be properly marked and have covers, preferably self-closing.

a. If plastic bags are used as inserts in waste containers, they shall be static dissipative or conductive and properly grounded.

b. Static-producing plastic bags shall not be allowed in sensitive explosives operations areas.

5.13.7 Explosives, dust from explosives, and other hazardous materials shall not be allowed to accumulate on structural members, radiators, heating coils, steam, gas, air, water supply lines, or electrical fixtures and equipment.

5.14 Sweeping Compounds

5.14.1 Where there may be exposed explosives on the floor, hot water or steam is the preferred method of cleaning. Do not use sweeping compounds containing incompatible materials on conductive floors.

5.14.2 When sweeping compounds are used, they shall be nonabrasive.

5.14.3 Sweeping compounds may be combustible but shall not have a closed cup flashpoint of less than 230 °F.

5.15 Explosives Recovery

All loose explosives recovered from sweeping floors of operating facilities shall be processed in accordance with manufacture’s recommendations.

5.16 RF Transmissions

5.16.1 Cellular phones, answer back pagers, personal data assistants, portable computers, portable hand-held radio transceivers and all other radio frequency transmitting devices (remote door openers, remote car starters, key fobs, W/LANs, etc.) operating in the Very High Frequency (VHF) and Ultra High Frequency (UHF) ranges, are prohibited within 15 feet of EEDs and NASA Standard Initiators (NSIs) unless evaluated and appropriate HA is performed by device.

5.16.2 RF emitting devices shall not be used within 15 feet of the following:

5.16.2.1 Exposed explosives or pyrotechnics

5.16.2.2 Electro-explosives

5.16.2.3 Electrically Initiated Devices

5.16.3 Projects (including emergency operations) requesting use of an RF emitting device at an explosive operating location, explosive location, or explosive facility, shall ensure only those RF emitting devices that meet, and tagged as meeting, the requirements of Appendix B and approved by the ESO are used.

Note 1: Similar or identical appearing devices may have differing transmitting capabilities (either frequency or power).

Note 2: Types of RF emitting devices include, but are not limited to: cellular phones; answer-back pagers; portable computers and personal data assistants with wireless capability; wireless network access points; fixed, mobile, and portable radio transceivers; remote key fobs; RF laboratory and test equipment; RF surveillance and ranging devices; X-ray machines; infrared ovens; wireless audio, video, and other information transmission systems; radio frequency identification readers and tags; and pulsed transmitters and radar systems.

5.17 Smoking

5.17.1 Smoking, matches, open flames, e-cigarettes and spark-producing devices shall be prohibited within 50 ft. of explosives areas.

5.17.2 Designated smoking areas beyond the 50 ft. limit are subject to the following minimum precautionary measures:

a. Proper receptacles for cigarettes, cigar butts, and pipes shall be provided.

b. Smoking shall be prohibited for personnel dressed in clothing/coveralls contaminated with explosives or flammable materials.

c. Persons who work with explosive materials and devices shall wash their hands before smoking.

5.17.3 A “No Smoking” sign shall be posted at each entrance to an explosives facility or storage area.

5.17.3.1 Signs are not required to be posted on facilities where Center policy mandates no smoking within the facility.

5.17.4 Smoking shall be prohibited in, on, or within 50 feet of any motor vehicle, trailer, rail car, or material handling equipment loaded with explosives or similar hazardous material items.

5.18 Personal Protective Equipment

PPE shall be issued to NASA employees, based on the particular hazard, at government expense and in accordance with 29 CFR 1910.132.

5.19 Clothing

5.19.1 Explosives clothing shall meet the following requirements:

a. Nonmetallic fasteners for coveralls

b. Easily removable coveralls/lab coats

c. Lattice pockets for coveralls

d. Tapered trouser legs, slacks, and sleeves

e. No cuffs on legs or sleeves

f. Coveralls shall extend over shoes/boots

g. Snuggly fitted waist and neck

h. Cotton undergarments

i. Cloth garments in accordance with MIL-C-43122 or untreated cotton

5.20 Conductive Footwear

5.20.1 Personnel who work on conductive flooring, conductive mats, or conductive runners where explosives or flammable vapors are present shall wear conductive footwear.

5.20.2 Visiting personnel who enter these areas and walk on conductive flooring materials shall also wear conductive footwear.

5.20.3 Leg stats are acceptable for visitors or transients only as long as their basic footwear is of non-sparking construction.

5.20.4 Personnel working on electrical equipment of facilities shall not wear conductive-sole shoes or other conductive footwear.

5.20.5 Conductive shoes with conductive composition soles shall meet the requirements of American Society for Testing and Materials ASTM F2412.

5.20.6 Testing of conductive shoes on individuals for use in explosives locations shall be made initially and daily thereafter to assure that the resistance from person to ground is less than 1 megohm.

5.20.7 Tests shall not be performed in rooms where exposed explosives are present.

5.21 Hand Tool Safety

Only non-sparking tools shall be used in locations or operations where sparks may cause a fire or explosion.

5.22 Hot Work Permits

A hot work permit shall be required for use of heat-producing equipment if the maximum operating temperature of the equipment exceeds the ignition temperature of the explosives.

5.23 Maintenance and Repairs to Equipment and Buildings

5.23.1 All new, modified, or repaired equipment to be used in explosives operations shall be examined and tested by competent designated operating personnel prior to use to assure safe working conditions.

5.23.2 If maintenance or repairs are to be conducted on equipment within the explosives area, the exposed explosives shall be removed from the immediate work area.

5.24 Electrical Testing of Explosives Components

5.24.1 Power Source

5.24.1.1 Electrical test equipment shall use the lowest possible power source.

5.24.1.2 The power source shall be incapable of initiating the explosives item under test.

5.24.2 Layout of Test Equipment

5.24.2.1 Test equipment shall not be placed in explosives areas unless approved for such use.

5.24.2.2 Operational shields shall be required for personnel protection unless the equipment is incapable of initiating the item being tested.

5.24.3 Use of Test Equipment

5.24.3.1 Test equipment shall be operated only when certified, within the calibration interval and in good working condition and by qualified personnel.

5.24.3.2 Test equipment shall only be used for the purpose which it was approved and designed.

5.25 Heat Conditioning of Explosives Equipment

5.25.1 All ovens, conditioning chambers, dry houses, and similar devices and facilities shall be provided with dual independent automatic heat controls and pressure relief devices. For devices or facilities heated by steam only, the requirements for dual automatic heat controls may be satisfied by controlling the steam pressure with a reducing valve (with a maximum pressure of 5 psi, unless otherwise authorized) on the main building steam supply and a thermostat on the device or in the facility.

5.25.2 Heat-conditioning devices shall be constructed to effectively vent overpressure from internal explosion. Blow-out panels, doors, and other venting apparatus should be restrained by barriers or catching devices to prevent excessive displacement in the event of an accidental explosion.

5.25.3 Heat-conditioning devices shall be effectively vented to permit the escape of dangerous gases that may evolve during the conditioning process.

5.25.4 Steam shall be used as the heating medium for conditioning devices, whenever practicable. If electric heating elements are used, the elements shall be so located so that there is no possibility of contact with explosives or flammable materials.

5.25.5 Air used for heating shall not be recirculated if the heating surfaces exceed a temperature of 228 °F or if the air contains materials that may collect on the heating elements.

5.25.6 Blades on fans for circulation of air shall be non-sparking material and, if possible, the electric motor installed on the exterior of the device.

5.25.7 Electrical equipment and fixtures in or on a heat-conditioning device shall be approved for the operation in the appropriate hazardous atmospheres, when used in explosives or flammable materials operations.

5.25.8 All noncurrent-carrying metal parts of a heat conditioning device shall be electrically interconnected and grounded. All heat-conditioning devices should be installed in an isolated location and arranged to afford maximum protection to personnel from the effects of an incident. Heat-conditioning devices should be separated from each other by distance or protective construction to prevent an explosion incident in one device from propagating to an adjacent device.

5.25.9 Heat-conditioning device operating procedures shall include the following conditions:

a. The explosives materials in the device shall be limited to the type and quantity authorized for the specific device.

b. The critical parameters of explosives compositions shall be known before processing in a heat-conditioning device.

c. The device shall not exceed established limits.

d. Heat-conditioning device temperatures shall be checked during operation at specified intervals. The checks should be conducted at more frequent intervals during periods of conditioning.

e. The conditioning devices, dusts, vacuum lines, and other parts subject to contamination by hazardous materials shall be cleaned prior to introducing a new or different item or composition for conditioning.

5.26 Classification System

5.26.1 Classification and transportation of explosives shall be in accordance with DOT regulations.

5.26.2 The DOT hazard classification system consists of the following nine hazard classes. Explosive materials and devices are included in Hazard Class 1.

Table 5-6. DOT Hazard Classification System

HAZARD CLASS	DESCRIPTION
1	Explosives
2	Gases
3	Flammable liquids
4	Flammable solids
5	Oxidizers & organic peroxides
6	Toxic
7	Radioactive
8	Corrosive
9	Miscellaneous

5.26.3 There are six divisions in Hazard Class 1:

a. Division 1.1 consists of explosives that have a mass explosion hazard. A mass explosion is one which affects almost the entire load instantaneously.

b. Division 1.2 consists of explosives that have a fragmentation hazard, but not a mass explosion hazard.

c. Division 1.3 consists of explosives that have a mass fire hazard, and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

d. Division 1.4 consists of explosives that present a moderate fire hazard. Explosive effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.

e. Division 1.5 consists of very insensitive explosives. This division comprises substances which have a mass explosion hazard, but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions.

f. Division 1.6 consists of extremely insensitive articles that do not have a mass explosion hazard. This division comprises articles that contain only extremely insensitive substances and that demonstrate a negligible probability of accidental initiation or propagation.

5.26.4 Compatibility group letters are used to specify the controls for transportation and storage to prevent an increase in hazard.

5.26.5 The full hazard classification code for an explosive consists of the division number followed by the compatibility group letter.

Table 5-7. Classification Codes

Compatibility Group Letter	Description of Substances or Article to be Classified	Classification Code(s)
A	Primary explosives substance	1.1A
B	Article containing a primary explosives substance and not containing two or more effective protective features. Some articles, such as detonators for blasting, detonator assemblies for blasting and primers, cap-type, are included, even though they do not contain primary explosives.	1.1B 1.2B 1.4B
C	Propellant explosives substance or other deflagrating explosives substance or article containing such explosives substance	1.1C 1.2C 1.3C 1.4C
D	Secondary detonating explosives substance or black powder or article containing a secondary detonating explosives substance, in each case without means of initiation and without a propelling charge, or article containing a primary explosives substance and containing two or more effective protective features	1.1D 1.2D 1.4D 1.5D
E	Article containing a secondary detonating explosives substance, without means of initiation, with a propelling charge (other than one containing flammable liquid or gel or hypergolic liquid)	1.1E 1.2E 1.4E
F	Article containing a secondary detonating explosives substance with its means of initiation, with a propelling charge (other than one containing flammable liquid or gel or hypergolic liquid) or without a propelling charge	1.1F 1.2F 1.3F 1.4F
G	Pyrotechnic substance or article containing a pyrotechnic substance, or article containing both an explosives substance and an illuminating, incendiary, tear-producing or smoke-producing substance (other than a water-activated article or one containing white phosphorus, phosphide or flammable liquid or gel or hypergolic liquid)	1.1G 1.2G 1.3G 1.4G
H	Article containing both an explosives substance and white phosphorus	1.2H 1.3H

Compatibility Group Letter	Description of Substances or Article to be Classified	Classification Code(s)
J	Article containing both an explosives substance and flammable liquid or gel	1.1J 1.2J 1.3J
K	Article containing both an explosives substance and a toxic chemical agent	1.2K 1.3K
L	Explosives substance or article containing an explosives substance and presenting a special risk (e.g., due to water-activation or presence of hypergolic liquids, phosphides or pyrophoric substances) needing isolation of each type	1.1L 1.2L 1.3L
N	Articles containing only extremely insensitive substances	1.6N
S	Substance or article so packed or designed that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit firefighting or other emergency response efforts in the immediate vicinity of the package	1.4S

(Reference: 49 CFR 173.52)

5.26.6 Materials with potentially energetic properties may be assigned to a different Hazard Class. Any item that has energetic properties, but is assigned to Hazard Class 2-9, is considered to have a NEW of zero for QD determinations.

5.26.7 A NASA organization sponsoring the development of a new explosives material or explosives device shall obtain a hazard classification in accordance with procedures required by 49 CFR 173.56.

5.27 Condition Codes

5.27.1 Condition codes (CC) are single letters which classify explosives materiel in storage. The purpose of CCs are to aid in the logistics of explosives material to identify the degree of serviceability and condition (readiness for issue and use).

5.27.2 Condition Codes A—SERVICEABLE (Issuable Without Qualification)

5.27.3 New, used, repaired, or reconditioned materiel that is serviceable and issuable without limitations or restrictions. Normal storage compatibility and transportation requirements applies.

5.27.4 Condition Codes B—SERVICEABLE (Limited Use)

5.27.5 Serviceable materiel that do not meet test specifications, but can be used for validating test equipment/procedures or training of personnel. Normal storage compatibility and transportation requirements applies.

5.27.6 Condition Codes C—UNSERVICEABLE

5.27.7 Materiel determined to be unserviceable, unusable due to a physical inspection, tear-down, or engineering decision (miss-fire, dropped or damaged). Normal storage compatibility does not apply. This materiel shall be stored separate, while awaiting disposition.

5.27.8 CC-A or CC-B explosives do not need to be physically marked or tagged but shall be reported as such in the inventory.

5.27.9 CC-C explosives shall be physically marked or tagged and reported as such in the inventory.

5.28 Segregation and Storage Principles

5.28.1 Segregation of explosives materials shall be in accordance with 49 CFR 177.848 and the Table 5-8 below.

5.28.2 Explosives shall not be stored with incompatible materials.

5.28.3 When necessary, dunnage shall be used to provide ventilation around explosive stocks and protect them from moisture and heat buildup.

5.28.4 Unserviceable materials shall be marked as such and separated from serviceable materials.

5.28.5 Explosives waste shall be marked as such and shall not be stored with non-hazardous materials or waste.

5.29 Mixed Storage

Explosives of different compatibility groups may only be stored as indicated in Table 5-8.

Table 5-8. Storage Compatibility Mixing Chart [a,b,c,d,e,f,g,h,i,j]

Groups	A	B	C	D	E	F	G	H	J	K	L	M	S
A	X	Z											
B	Z	X	Z	Z	Z	Z	Z					X	X
C		Z	X	X	X	Z	Z					X	X
D		Z	X	X	X	Z	Z					X	X
E		Z	X	X	X	Z	Z					X	X
F		Z	Z	Z	Z	X	Z					Z	X
G		Z	Z	Z	Z	Z	X					Z	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	Z	Z					X	X
S		X	X	X	X	X	X	X	X			X	X

(Reference: DoD 6055.09, March 12, 2012)

NOTES:
[a] A “X” at an intersection indicates that the groups may be combined in storage. Otherwise,

mixing is either prohibited or restricted per footnote b.

[b] A "Z" at an intersection indicates that when warranted by operational considerations or magazine non-availability and when safety is not sacrificed, mixed storage of limited quantities of some items of different compatibility groups may be approved by the ESO. Such approval documentation must be kept on site. Component approval of mixed storage in compliance with Z intersections does not require a waiver or exemption. Mixed storage of items within groups where no X or Z exists at that pair's intersection beyond the prohibitions and limitations of footnote g, however, requires an approved waiver or exemption. Examples of acceptable storage combinations are:

1. HD 1.1A initiating explosives with HD 1.1B fuzes not containing two or more effective protective features.
2. HD 1.3C bulk propellants or bagged propelling charges with HD 1.3G pyrotechnic substances.

[c] Equal numbers of separately packaged components of hazard-classified complete rounds of any single type of explosives may be stored together. When so stored, compatibility is that of the complete round.

[d] Group K requires not only separate storage from other groups, but also may require separate storage within the group. The controlling ESO will determine which items under Group K may be stored together and those that must be stored separately. Such documentation must be kept on site.

[e] Explosives classed outside Class 1 may be assigned the same Group as Class 1 explosives containing similar hazard features, but where the explosive hazard predominates. Non-Class 1 explosives and Class 1 explosives assigned the same Group may be stored together.

[f] The ESO may authorize explosives "Practice" or "Training" by nomenclature, regardless of the Group assigned, to be stored with the tactical explosives it simulates. Such documentation must be kept on site.

[g] The ESO may authorize the mixing of Groups, except items in Groups A, K, and L, in limited quantities generally of 1,000 lbs [454 kg] total NEWQD or less. Such documentation must be kept on site.

[h] For purposes of mixing, all explosives must be packaged in its DOT-approved shipping containers. Explosives containers will not be opened for issuing items from storage locations. Outer containers may be opened in storage locations for inventorying and for magazines storing only HD 1.4 items, unpacking, inspecting, and repackaging the HD 1.4 ammunition.

[i] When using the Z mixing authorized by footnote b for articles of either Group B or F, each will be segregated in storage from articles of other Groups by means that prevent propagation of Group B or F articles to articles of other Groups.

[j] If dissimilar HD 1.6N AE are mixed together and have not been tested to ensure non-propagation, the mixed explosives are individually considered to be HD 1.2.1D or HD 1.2.2D based on their NEWQD or overriding fragmentation characteristics for purposes of transportation and storage. When mixing Group N explosives with Group B through G or with Group S, see section 5-30. to determine the HD for the mixture.

5.30 QD Principles

5.30.1 This section outlines explosives QD criteria and related standards for storing and handling explosives.

5.30.2 The QD criteria and tables prescribe acceptable minimum separation distances for storing and handling explosives. They also state the maximum quantities of the various class/division of explosives allowed in any one location. Explosives limits set up locally shall be no greater than needed for a safe operation.

5.30.3 Operations and personnel shall be located to minimize exposure to hazards.

5.30.4 Separation of explosives locations is needed to minimize explosives hazards. Locations that contain explosives shall be separated from the following.

a. Other locations that contain explosives.

b. Inhabited buildings, including structures or other places not directly related to explosives operations, where people usually assemble or work.

c. Public traffic routes (PTR).

d. Operating lines or buildings, including structures or other places where people usually assemble or work, that are directly related to explosives operations.

e. Petroleum, oil, and lubricant storage.

f. Utilities, buildings, and facilities.

g. Aircraft parking and storage areas, runways and approach zones, and taxiways.

h. Facility boundaries.

5.30.5 Magazines are sited relative to each other so that propagation of explosion from one to another is unlikely. Actual siting requirements are influenced both by the construction features of the magazines and the types and quantities of explosives.

5.30.6 Hazardous explosives materials shall not be stored within an operating building except for the minimum quantities necessary to maintain individual operations.

5.30.7 Explosives that are part of the work in process within operational buildings may be stored during nonoperational hours, provided the following requirements are strictly observed:

a. Explosives limits shall not be exceeded.

b. Compatibility requirements shall be met.

c. Containers of bulk explosives or propellants shall be properly secured and covered.

d. Processing equipment shall be empty and cleaned.

e. The building shall be equipped with an automatic sprinkler system.

f. Applicable placards (see 5.3) shall be displayed.

g. The building is locked when unattended.

5.31 Quantity of Explosives and Distances

5.31.1 The basis for determining required separation distances are:

a. The NEW of the HD of explosives present in an explosives facility.

b. The NEW of the HD requiring the greatest separation establishes the QD for the facility when it is used for multiple operations.

c. The NEW for the High Performance Magazines (HPM) is based on its maximum credible event (MCE) and shall not exceed 60,000 lbs.

5.31.2 In the assessment of the hazard associated with a given situation, the principal effects of the explosives output to be considered are blast, pressure, whether the item is propulsive, primary and secondary fragments, thermal hazards, and toxicity hazards. Variances are available as an alternative to the QD requirements published in the QD tables of this document. Variances shall be reviewed by the ESO and approved by the Center Director. These distance requirements may be reduced if any one of the three following conditions are met:

a. Engineering risk assessment or testing/analyses of blast, fragment, and thermal hazards show acceptable exposure as defined in this section; or

b. Use of protective construction and/or dividing walls, designed with approved methods, or protective shields/barricades reduce blast, fragment, and thermal hazards to acceptable levels.

c. An alternate siting approach based on testing and analysis to determine the MCE in lieu of applying QD tables shall be permitted for any explosives classification used as a propellant in space vehicle launch applications and associated ground testing provided all of the following requirements are met:

(1) The responsible organization shall develop a test and analysis plan including modeling requirements and acceptance thresholds for QD siting based on MCE and submit it to the ESO and Center Director for review and approval prior to implementation.

(2) The alternate MCE approach shall consider the maximum credible hazard associated with propagation, pressure waves, heat flux, fragmentation, and reaction byproducts.

(3) Analysis shall include risk analysis as well as any modeling of the reaction and its effects required to demonstrate applicability of testing and extrapolations, and QD determination.

(4) The alternate MCE approach shall take into account or require engineering and procedural controls, separation by time, distance, or barriers (for blast wave coalescence, heat flux, or other characteristics of the reaction), and actual material reaction characteristics.

(5) The alternate MCE approach shall take into account the actual reaction characteristics, whether greater or less than those in conventional models.

(6) For those cases in which radiant heat flux governs:

(a) Credible radiant heat flux scenarios for the heat source shall be based on actual material characteristics, source location, ignition scenarios, shielding, etc.

(b) IBD shall be no less than the distance which will prevent second degree burns. This distance will be determined based on an exposure period less than the total burn duration, provided the following conditions are met:

(i) Credible escape/mitigation scenarios will be developed and validated.

(ii) Training programs will be developed and implemented to ensure that personnel are aware of the hazard and understand both what action is required of them and the importance that action be taken immediately.

(iii) Exposure periods greater than t (seconds, in the following formula) shall not be acceptable:

$$t = 200q^{-1.46}$$

where:
t = time (seconds) to blister
q = incident thermal radiation (kW/m^2) (Incident heat flux less than 1.8 kW/m^2 need not be considered.

Note: This formula is from the SFPE Engineering Guide, "Predicting 1st and 2nd Degree Burns from Thermal Radiation."

(iv) Buildings within conventional IBD arcs will be capable of withstanding the expected radiant heat flux at their sited distance to the extent that they continue to provide protection to personnel.

(7) The final QD determination based on the MCE shall be reviewed by the ESO and approved by the Center Director.

5.31.3 Separation distances are measured along straight lines.

5.31.4 Measurements of distance for determining the maximum allowable quantity of explosives shall be made to the nearest part of an Exposed Site (ES) from:

a. The nearest wall of the PES.

b. The exterior of the nearest intervening wall to the controlling explosives stack, when the PES is subdivided.

5.31.5 When an explosives conveyance (e.g., railroad car or motor vehicle) containing explosives is not separated from a PES in such a manner as to prevent mass detonation, then the conveyance and PES shall be considered as a unit and their NEW shall be summed.

5.31.6 If the explosives are separated so that mass explosion will not occur, the separation distance shall be measured from the nearest controlling PES or conveyance to an ES.

5.31.7 Determination of NEW

a. The quantity of explosives in a magazine, operating building, or other explosives site is considered to be the NEW of the controlling class of explosives contained therein (the class requiring the greatest separation). The total quantity of explosives in a facility is calculated as shown below.

(1) Mass-explosion (HD 1.1). The NEW is the total weight of all HE.

(2) Non-mass explosion, fragment producing (HD 1.2). The NEW is the total weight of all HE.

(3) Mass fire, minor blast, or fragment (HD 1.3). The NEW is the total weight of all HE, propellant, and pyrotechnics.

(4) Moderate fire, no blast, or fragment (HD 1.4). The NEW is the total weight of all HE, propellant, and pyrotechnics.

(5) Very insensitive, with mass-explosion (HD 1.5). The NEW is the total weight of all HE.

(6) Extremely insensitive (HD 1.6). The NEW is the total weight of Electrically Initiated Devices (EIDs).

(7) Exclusions. Device fillers that do not contribute to explosives effects are excluded when determining NEW.

5.31.8 Determining the NEW for Mixed HDs

a. The presence of HD 1.4 does not affect the NEW of mixed HD. However, for QD determinations, HD 1.4 criteria shall be considered.

b. When HD 1.1 is mixed with any other HD, the mixture is treated as HD 1.1, except:

(1) HD 1.1 with HD 1.2. Whichever of the following generates the largest QD is used: a) sum the NEW for HD 1.1 and NEW for HD 1.2 and treat the mixture as HD 1.1, or b) the NEW of the mixture is the NEW of the HD 1.2 subdivision requiring the largest QD.

(2) HD 1.1 with HD 1.3. The NEW for HD 1.1 and the NEW for HD 1.3 are summed and the mixture treated as HD 1.1.

(3) HD 1.1 with HD 1.6. The NEW for HD 1.1 and the NEW for HD 1.6 are summed and the mixture treated as HD 1.1.

c. When HD 1.2 is mixed with any other HD except HD 1.1, the mixture is treated as HD 1.2, except:

(1) HD 1.2 with HD 1.3. The NEW for the mixture is the NEW of the HD requiring the largest QD.

(2) HD 1.2 with HD 1.6. The HD 1.6 is treated as HD 1.2.

d. When HD 1.3 is mixed with any other HD except HD 1.1 and HD 1.2, the mixture is treated as HD 1.3.

5.32 Hazard Divisions and QD Tables

5.32.1 Hazard Division 1.1

5.32.1.1 The IBD shall be maintained between a PES and buildings or structures, other than operating buildings, occupied in whole or in part by human beings, both within and

outside NASA establishments. Locations to which the IBD applies may include but are not limited to the following:

a. Inhabited buildings, administrative and housing areas.

b. Center/facility boundaries.

c. Facilities that, by reason of their vital nature, or high intrinsic value of their contents, should not be placed at risk.

d. PTR with high traffic density.

5.32.1.2 Separation distances required from ECMs and other types of PESs to inhabited buildings are listed for various quantities of Hazard Division 1.1 in Table 5-9 and shall be maintained. Specified separations from ECM take into account reductions in blast overpressure attributable to the earth cover of the magazines.

5.32.1.3 PTR distance (PTRD) from ECM and other types of PESs listed for various quantities of Hazard Division 1.1 in Table 5-9, shall be applied to the following locations:

a. PTR with medium and low traffic densities.

b. On-Center roads. NASA Centers may provide Center/Facility-related personnel, transiting the Explosives Safety Quantity Distance (ESQD) arc of explosives areas protection less than 60% of IBD, provided:

(1) The risks are evaluated and documented in the Explosives Site Plan. The Centers use appropriate methods to inform transients of potential risks (e.g., written acknowledgment of the risk by vendors or others with a recurring need to transit the ESQD, warning signs, flashing lights, physical barriers). The Center's decision to provide transients protection at less than 60% of IBD shall be based on:

(a) Operational necessity

(b) The operation being performed (e.g., static storage, maintenance, and production)

(c) Operational activity cycle

(d) Alternate routes

(e) Traffic density

(f) Accident records

(g) Time interval of exposure

(h) Type and quantity of munitions in proximity to the area transited

(i) The closest distance from the area transited to the PES

(j) The need for Center-related personnel to transit the ESQD arc

(2) Reviewed as changes occur to either operations, which would increase the explosives safety risk, or the number of exposed individuals, and upon change of the approving authority.

c. Aircraft passenger loading and unloading areas that do not include any structures

5.32.2 All new construction of explosives storage and operating facilities, and any change in operations within existing facilities that increases the explosives safety risk, shall provide both the general public and Center/Facility-related personnel who are not involved in explosives-related operations protection equal to or greater than 60% of IBD.

Table 5-9. Hazard Division 1.1 Inhabited Building and Public Traffic Route Distances

NEWQD	IBD From:				PTRD From:			
	Front[a,b]	ECM Side[a]	Rear[c]	Other PES[d]	Front[e,f]	ECM Side[e]	Rear[e]	Other PES[e]
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
1	500	250	250	Footnote d	300	150	150	Footnote e
0.45	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
1.5	500	250	250		300	150	150	
0.68	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
2	500	250	250		300	150	150	
0.91	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
3	500	250	250		300	150	150	
1.4	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
5	500	250	250		300	150	150	
2.3	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
7	500	250	250		300	150	150	
3.2	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
10	500	250	250		300	150	150	
4.5	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
15	500	250	250		300	150	150	
6.8	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
20	500	250	250		300	150	150	
9.1	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
30	500	250	250		300	150	150	
13.6	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
50	500	250	250		300	150	150	
22.7	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
70	500	250	250		300	150	150	
31.8	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
100	500	250	250		300	150	150	
45.4	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
150	500	250	250		300	150	150	
68	*152.4*	*76.2*	*76.2*		*91.4*	*45.7*	*45.7*	
200	700	250	250		420	150	150	
90.7	*213.6*	*76.2*	*76.2*		*128*	*45.7*	*45.7*	

NEWQD	IBD From:				PTRD From:			
	Front[a,b]	ECM Side[a]	Rear[c]	Other PES[d]	Front[e,f]	ECM Side[e]	Rear[e]	Other PES[e]
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
300	700	250	250		420	150	150	
136.1	*213.6*	*76.2*	*76.2*		*128*	*45.7*	*45.7*	
450	700	250	250		420	150	150	
204.1	*213.6*	*76.2*	*76.2*		*128*	*45.7*	*45.7*	
500	1250	1250	1250	1250	750	750	750	750
226.8	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
700	1250	1250	1250	1250	750	750	750	750
317.5	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
1000	1250	1250	1250	1250	750	750	750	750
453.6	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
1500	1250	1250	1250	1250	750	750	750	750
680.4	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
2000	1250	1250	1250	1250	750	750	750	750
907.2	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
3000	1250	1250	1250	1250	750	750	750	750
1360.8	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
5000	1250	1250	1250	1250	750	750	750	750
2268	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
7000	1250	1250	1250	1250	750	750	750	750
3175.1	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
10000	1250	1250	1250	1250	750	750	750	750
4535.9	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
15000	1250	1250	1250	1250	750	750	750	750
6803.9	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
20000	1250	1250	1250	1250	750	750	750	750
9071.8	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
30000	1250	1250	1250	1250	750	750	750	750
13607.7	*381*	*381*	*381*	*381*	*228.6*	*228.6*	*228.6*	*228.6*
45000	1250	1250	1250	1423	750	750	750	854
20411.6	*381*	*381*	*381*	*433.7*	*228.6*	*228.6*	*228.6*	*260.3*
50000	1289	1289	1250	1474	774	774	750	884
22679.5	*392.9*	*392.9*	*381*	*448.9*	*235.7*	*235.7*	*228.6*	*269.4*
70000	1442	1442	1250	1649	865	865	750	989
31751.3	*439.5*	*439.5*	*381*	*502.2*	*263.7*	*263.7*	*228.6*	*301.3*
100000	1625	1625	1250	1857	975	975	750	1114
45359	*495*	*495*	*381*	*565.6*	*297*	*297*	*228.6*	*339.4*
150000	2177	2177	1804	2346	1306	1306	1083	1408
68038.5	*663.5*	*663.5*	*550*	*715.2*	*398.1*	*398.1*	*330*	*429.1*
200000	2680	2680	2469	2770	1608	1608	1481	1662
90718	*816.8*	*816.8*	*752.5*	*844.4*	*490.1*	*490.1*	*451.5*	*506.6*
250000	3149	3149	3149	3151	1889	1889	1889	1891
113397.5	*959.8*	*959.8*	*959.8*	*960.4*	*575.9*	*575.9*	*575.9*	*576.2*

NEWQD	IBD From:				PTRD From:			
	Front[a,b]	ECM Side[a]	Rear[c]	Other PES[d]	Front[e,f]	ECM Side[e]	Rear[e]	Other PES[e]
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
300000	3347	3347	3347	3347	2008	2008	2008	2008
136077	*1020.5*	*1020.5*	*1020.5*	*1020.5*	*612.3*	*612.3*	*612.3*	*612.3*
500000	3969	3969	3969	3969	2381	2381	2381	2381
226795	*1209.9*	*1209.9*	*1209.9*	*1209.9*	*725.9*	*725.9*	*725.9*	*725.9*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a. For NEWQD < 45,000 lbs [20,412 kg], the distance is controlled by fragments. When fragments are absent or if the Hazardous Fragment Distance (HFD) (1/600 ft^2 [1/55.7 m^2]) is less than the blast hazard range, then the blast criteria in this footnote may be used.

English EQNs (NEWQD in lbs, d in ft)

NEWQD ≤ 45,000 lbs:	$d = 35*NEWQD^{1/3}$
45,000 lbs < NEWQD ≤ 100,000 lbs:	$d = 35*NEWQD^{1/3}$
100,000 lbs < NEWQD ≤ 250,000 lbs:	$d = 0.3955*NEWQD^{0.7227}$
250,000 lbs < NEWQD:	$d = 50*NEWQD^{1/3}$

Metric EQNs (NEWQD in kg, d in m)

NEWQD ≤ 20,412 kg:	$d = 13.88*NEWQD^{1/3}$
20,412 kg < NEWQD ≤ 45,359 kg:	$d = 13.88*NEWQD^{1/3}$
45,359 kg < NEWQD ≤ 113,398 kg:	$d = 0.2134*NEWQD^{0.7227}$
113,398 kg < NEWQD:	$d = 19.84*NEWQD^{1/3}$

English EQNs (d in ft, NEWQD in lbs)

d ≤ 1,245 ft:	$NEWQD = d^3/42{,}875$
1,245 ft < d ≤ 1,625 ft:	$NEWQD = d^3/42{,}875$
1,625 ft < d ≤ 3,150 ft:	$NEWQD = 3.60935*d^{1.3837}$
3,150 ft < d:	$NEWQD = d^3/125{,}000$

Metric EQNs (d in m, NEWQD in kg)

d ≤ 379.3 m:	$NEWQD = d^3/2{,}674.04$
379.3 m < d ≤ 495.0:	$NEWQD = d^3/2{,}674.04$
495.0 m < d ≤ 960.3 m:	$NEWQD = 8.4761*d^{1.3837}$
960.3 m < d:	$NEWQD = d^3/7{,}809.53$

b. IBD for frontal exposures applies to all directions from HPMs. The maximum credible event (MCE) in the HPM is used as the NEWQD. The limit on the design MCE in an HPM is 60,000 lbs [27,215 kg].

c. For NEWQD < 100,000 lbs [45,359 kg], the distance is controlled by fragments and debris. When fragments and debris are absent or the range to a hazardous debris density of 1/600 ft^2 [1/55.7 m^2] is less than the blast hazard range, then the blast criteria may be used.

English EQNs (NEWQD in lbs, d in ft)

NEWQD ≤ 100,000 lbs:	$d = 25*NEWQD^{1/3}$
100,000 lbs < NEWQD ≤ 250,000 lbs:	$d = 0.004125*NEWQD^{1.0898}$
250,000 lbs < NEWQD:	$d = 50*NEWQD^{1/3}$

Metric EQNs (NEWQD in kg, d in m)

NEWQD ≤ 45,359 kg:	$d = 9.92*NEWQD^{1/3}$
45,359 kg < NEWQD ≤ 113,398 kg:	$d = 0.002976*NEWQD^{1.0898}$
113,398 kg < NEWQD:	$d = 19.84*NEWQD^{1/3}$

	English EQNs (d in ft, NEWQD in lbs)	
	d ≤ 1,160 ft:	NEWQD = $d^3/15{,}625$
	1,160 ft < d ≤ 3,150 ft:	NEWQD =$154.2006*d^{0.91760}$
	3,150 ft < d:	NEWQD = $d^3/125{,}000$
	Metric EQNs (d in m, NEWQD in kg)	
	d ≤ 353.8 m:	*NEWQD = $d^3/976.19$*
	353.8 m < d ≤ 960.3 m:	*NEWQD = $208.0623*d^{0.91760}$*
	960.3 m < d:	*NEWQD = $d^3/7{,}809.53$*
d	For NEWQD < 30,000 lbs [13,608 kg], the distance is controlled by fragments and debris. Lesser distances may be permitted for certain situations.	
	English EQNs (NEWQD in lbs, d in ft)	
	30,000 lbs < NEWQD ≤ 100,000 lbs:	d = $40*NEWQD^{1/3}$
	100,000 lbs < NEWQD ≤ 250,000 lbs:	d = $2.42*NEWQD^{0.577}$
	250,000 lbs < NEWQD:	d = $50*NEWQD^{1/3}$
	Metric EQNs (NEWQD in kg, d in m)	
	13,608 kg < NEWQD ≤ 45,359 kg:	*d = $15.87*NEWQD^{1/3}$*
	45,359 kg < NEWQD ≤ 113,398 kg:	*d = $1.1640*NEWQD^{0.577}$*
	113,398 kg < NEWQD:	*d = $19.84*NEWQD^{1/3}$*
	English EQNs (d in ft, NEWQD in lbs)	
	1,243 ft < d ≤ 1,857 ft:	NEWQD = $d^3/64{,}000$
	1,857 ft < d ≤ 3,150 ft:	NEWQD = $0.2162*d^{1.7331}$
	3,150 ft < d:	NEWQD = $d^3/125{,}000$
	Metric EQNs (d in m, NEWQD in kg)	
	378.6 m < d ≤ 565.6 m:	*NEWQD = $d^3/3{,}989.42$*
	565.6 m < d ≤ 960.3 m:	*NEWQD = $0.7686*d^{1.7331}$*
	960.3 m < d:	*NEWQD = $d^3/7{,}809.53$*
e	Computed as 60% of applicable IBD.	
f	PTRD applies to all directions from an HPM. The MCE in the HPM is used as the NEWQD.	

5.32.3 The ILD shall be maintained between structures and an operating line. The ILD is listed in Table 5-10 for Hazard Division 1.1 explosives.

5.32.3.1 ILD shall be applied to the following locations:

a. Buildings housing production, renovation, or maintenance operation.

b. Security alert force buildings.

c. Break rooms and change houses used exclusively by personnel employed in operating lines.

d. Temporary holding areas for trucks or railcars containing explosives to service production or maintenance facilities.

e. Field operations in magazine areas when performing minor maintenance, preservation, packaging, or surveillance inspection.

f. Unmanned auxiliary power facilities, transformer stations, water treatment and pollution abatement facilities, and other utility installations which serve the PES and are not an integral function in the PES, and loss of which would not create an immediate

secondary hazard. Exception: Unmanned auxiliary power generation or conversion facilities exclusively supplying power to the explosives storage area.

g. Dunnage preparation and similar support structures housing non-explosives operations.

h. Service magazines that are part of operating lines. The ILD may be no less than the ILD required for the quantity of explosives contained in the service magazine.

i. Exposures as indicated in the next section if blast suppression and structure hardening provide comparable protection for personnel and equipment involved.

5.32.3.2 ILD (without barricading) shall be applied to the following locations:

a. Surveillance, maintenance, inspection buildings and labor-intensive operations closely related to the PES.

b. Comfort, safety, and convenience occupied buildings exclusively in support of the PES (such as lunchrooms, motor pools, area offices, auxiliary fire stations, transportation dispatch points, and shipping and receiving buildings).

c. Parallel operating lines from one another provided explosives involved in each operating line present similar hazards. The criticality or survivability of one or more of the operating lines may require that each line be given an inhabited building level of protection.

d. Operations and training functions that are manned or attended exclusively by personnel of the organization operating the PES. This includes break rooms, operation offices, and similar functions for organizations operating the facility.

e. Auxiliary power and utilities functions which include auxiliary power plants; compressor stations; electric power transformers; tool and consumable supplies storage and issue; and handling equipment service, battery charging, and minor repair.

f. Service magazines that are part of operating lines. The ILD may be no less than the ILD required for the quantity and type of explosives contained in the service magazine.

g. ECMs and / or HPMs. Testing has shown some attenuation of the airblast overpressure occurs out the sides and rear of ECM and / or HPM and a slight increase out the front of an ECM, relative to the unconfined surface burst. ILDs for Hazard Division 1.1 are given in Table 5-12.

Table 5-10. Hazard Division 1.1, Intraline Distances

NEWQD	Barricaded Distance[a]	Unbarricaded Distance[b]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
50c	33	66
22.7c	*10.1*	*20.2*
70	37	74

NEWQD	Barricaded Distance[a]	Unbarricaded Distance[b]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
31.8	*11.3*	*22.6*
100	42	84
45.4	*12.7*	*25.5*
150	48	96
68	*14.6*	*29.1*
200	53	105
90.7	*16*	*32.1*
300	60	120
136.1	*18.4*	*36.7*
500	71	143
226.8	*21.8*	*43.5*
700	80	160
317.5	*24.4*	*48.7*
1,000	90	180
453.6	*27.4*	*54.9*
1,500	103	206
680.4	*31.4*	*62.8*
2,000	113	227
907.2	*34.6*	*69.1*
3,000	130	260
1,360.80	*39.6*	*79.1*
5,000	154	308
2,268.00	*46.9*	*93.8*
7,000	172	344
3,175.10	*52.5*	*104.9*
10,000	194	388
4,535.90	*59.1*	*118.2*
15,000	222	444
6,803.90	*67.6*	*135.3*
20,000	244	489
9,071.80	*74.5*	*148.9*
30,000	280	559
13,607.70	*85.2*	*170.5*
50,000	332	663
22,679.50	*101.1*	*202.1*
70,000	371	742
31,751.30	*113*	*226.1*
100,000	418	835
45,359.00	*127.3*	*254.6*
150,000	478	956
68,038.50	*145.7*	*291.5*
200,000	526	1,053
90,718.00	*160.4*	*320.8*

NEWQD	Barricaded Distance[a]	Unbarricaded Distance[b]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
300,000	602	1,205
136,077.00	*183.6*	*367.2*
500,000[d]	714	1,429
226,795.0[d]	*217.7*	*435.4*
700,000	799	1,598
317,513.00	*243.6*	*487.1*
1,000,000	900	1,800
453,590.00	*274.3*	*548.6*
1,500,000	1,030	2,060
680,385.00	*314*	*628*
2,000,000	1,134	2,268
907,180.00	*345.6*	*691.2*
3,000,000	1,298	2,596
1,360,770.00	*395.6*	*791.2*
5,000,000	1,539	3,078
2,267,950.00	*469*	*938.1*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	English EQNs (d in ft, NEWQD in lbs) $d = 9*NEWQD^{1/3}$ $NEWQD = d^3/729$ *Metric EQNs (d in m, NEWQD in kg)* *$d = 3.57*NEWQD^{1/3}$* *$NEWQD = d^3/45.511$*
b	English EQNs (d in ft, NEWQD in lbs) $d = 18*NEWQD^{1/3}$ NEWQD = d3/5,832 Metric EQNs (d in m, NEWQD in kg) $d = 7.14*NEWQD^{1/3}$ $NEWQD = d^3/364.086$
c	For less than 50 lbs [22.7 kg], less distance may be used when structures, blast mats, and the like can completely contain fragments and debris. This table is not applicable when blast, fragments, and debris are completely confined, as in certain test firing barricades.
d	Quantities above 500,000 lbs [226,795 kg] NEWQD are authorized only for HD 1.1 energetic liquids.

Table 5-11. Hazard Division 1.1, Intraline Distances from ECMs

NEWQD	Barricaded			Unbarricaded		
	Front[a]	Side[b]	Rear[c]	Front[d]	Side[e]	Rear[f]
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
50	37	26	22	66	59	44
22.7	*11.2*	*7.9*	*6.7*	*20.2*	*18*	*13.5*
70	41	29	25	74	66	49
31.8	*12.6*	*8.8*	*7.5*	*22.6*	*20.1*	*15.1*
100	46	32	28	84	74	56
45.4	*14.2*	*9.9*	*8.5*	*25.5*	*22.6*	*17*
150	53	37	32	96	85	64
68	*16.2*	*11.3*	*9.7*	*29.1*	*25.9*	*19.4*
200	58	41	35	105	94	70
90.7	*17.8*	*12.5*	*10.7*	*32.1*	*28.5*	*21.4*
300	67	47	40	120	107	80
136.1	*20.4*	*14.3*	*12.2*	*36.7*	*32.7*	*24.5*
500	79	56	48	143	127	95
226.8	*24.2*	*17*	*14.5*	*43.5*	*38.7*	*29*
700	89	62	53	160	142	107
317.5	*27.1*	*19*	*16.2*	*48.7*	*43.3*	*32.5*
1000	100	70	60	180	160	120
453.6	*30.5*	*21.4*	*18.3*	*54.9*	*48.8*	*36.6*
1500	114	80	69	206	183	137
680.4	*34.9*	*24.5*	*20.9*	*62.8*	*55.9*	*41.9*
2000	126	88	76	227	202	151
907.2	*38.4*	*26.9*	*23*	*69.1*	*61.5*	*46.1*
3000	144	101	87	260	231	173
1360.8	*44*	*30.8*	*26.4*	*79.1*	*70.4*	*52.7*
5000	171	120	103	308	274	205
2268	*52.2*	*36.5*	*31.3*	*93.8*	*83.4*	*62.5*
7000	191	134	115	344	306	230
3175.1	*58.4*	*40.9*	*35*	*104.9*	*93.3*	*70*
10000	215	151	129	388	345	259
4535.9	*65.7*	*46*	*39.4*	*118.2*	*105.1*	*78.8*
15000	247	173	148	444	395	296
6803.9	*75.2*	*52.7*	*45.1*	*135.3*	*120.3*	*90.2*
20000	271	190	163	489	434	326
9071.8	*82.8*	*58*	*49.6*	*148.9*	*132.4*	*99.3*
30000	311	218	186	559	497	373
13607.7	*94.8*	*66.4*	*56.8*	*170.5*	*151.6*	*113.6*
50000	368	258	221	663	589	442
22679.5	*112.4*	*78.7*	*67.4*	*202.1*	*179.7*	*134.7*
70000	412	288	247	742	659	495
31751.3	*125.7*	*88*	*75.4*	*226.1*	*201.1*	*150.7*
100000	464	325	278	835	743	557

NEWQD	Barricaded			Unbarricaded		
	Front[a]	Side[b]	Rear[c]	Front[d]	Side[e]	Rear[f]
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
45359	*141.6*	*99.1*	*84.9*	*254.6*	*226.5*	*169.8*
150000	531	372	319	956	850	653
68038.5	*162.1*	*113.5*	*97.2*	*291.5*	*259.2*	*199.1*
200000	585	409	351	1053	936	746
90718	*178.4*	*124.9*	*106.9*	*320.8*	*285.3*	*227.4*
300000	669	469	402	1205	1071	937
136077	*204.2*	*143*	*122.4*	*367.2*	*326.6*	*285.7*
500000	715	714	714	1429	1429	1429
226795	*218*	*217.7*	*217.7*	*435.4*	*435.4*	*435.4*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

c	English EQNs (NEWQD in lbs, d in ft)	
	NEWQD < 300,000 lbs:	$d = 6*NEWQD^{1/3}$
	300,000 lbs < NEWQD < 400,000 lbs:	$d = (-3.059 + 3.0228 \times 10^{-5}*NEWQD) * NEWQD^{1/3}$
	NEWQD > 400,000 lbs:	$d = 9*NEWQD^{1/3}$
	d <402 ft:	$NEWQD = d^3/216$
	402 ft < d < 665 ft:	$NEWQD = 148{,}160 + 379.7*d$
	d > 665 ft:	$NEWQD = d^3/729$
	Metric EQNs (NEWQD in kg, d in m)	
	NEWQD < 136,077 kg:	$d = 2.38*NEWQD^{1/3}$
	136,077 kg < NEWQD < 181,436 kg:	$d = (-1.2135 + 2.6437 \times 10^{-5}*NEWQD) *NEWQD^{1/3}$
	NEWQD > 181,436 kg:	$d = 3.57*NEWQD^{1/3}$
	d < 122.6 m:	$NEWQD = d^3/13.485$
	122.6 m < d < 202.8 m:	$NEWQD = 67{,}206 + 565.05*d$
	d > 202.8 m:	$NEWQD = d^3/45.511$
d	English EQNs (NEWQD in lbs, d in ft)	
	NEWQD < 500,000 lbs:	$d = 18*NEWQD^{1/3}$
	d < 1,429 ft:	$NEWQD = d^3/5{,}832$
	Metric EQNs (NEWQD in kg, d in m)	
	NEWQD < 226,795 kg:	$d = 7.14*NEWQD^{1/3}$
	d > 435.4 m:	$NEWQD = d^3/364.08$
e	English EQNs (NEWQD in lbs, d in ft)	
	NEWQD < 300,000 lbs:	$d = 16*NEWQD^{1/3}$
	300,000 lbs < NEWQD < 400,000 lbs:	$d = (9.9683 + 2.0135 \times 10^{-5}*NEWQD) *NEWQD^{1/3}$
	NEWQD > 400,000 lbs:	$d = 18*NEWQD^{1/3}$
	d < 1071 ft:	$NEWQD = d^3/4{,}096$
	1,071 ft < d < 1,328 ft:	$NEWQD = -118{,}180 + 390.35*d$
	d > 1,328 ft:	$NEWQD = d^3/5{,}832$

	Metric EQNs (NEWQD in kg, d in m)	
	NEWQD < 136,077 kg:	*$d = 6.35 * NEWQD^{1/3}$*
	136,077 kg < NEWQD < 181,436 kg:	*$d = (3.9544 + 1.76097 \times 10^{-5} * NEWQD) * NEWQD^{1/3}$*
	NEWQD > 181,436 kg:	*$d = 7.14 * NEWQD^{1/3}$*
	d < 326.6 m:	*$NEWQD = d^3/255.709$*
	122.6 m < d < 202.8 m:	*NEWQD = -53,605 + 580.89*d*
	d > 404.7 m:	*$NEWQD = d^3/364.086$*
f	English EQNs (NEWQD in lbs, d in ft)	
	NEWQD < 100,000 lbs:	$d = 12 * NEWQD^{1/3}$
	100,000 lbs < NEWQD < 300,000 lbs:	$d = (11.521 + 1.9918 \times 10^{-6} * NEWQD + 2.0947 \times 10^{-11} * NEWQD^2) * NEWQD^{1/3}$
	300,000 lbs < NEWQD < 400,000 lbs:	$d = (1.9389 + 4.0227 \times 10^{-5} * NEWQD) * NEWQD^{1/3}$
	NEWQD > 400,000 lbs:	$d = 18 * NEWQD^{1/3}$
	d < 557 ft:	$NEWQD = d^3/1,728$
	557 ft < d < 938 ft:	NEWQD = -193,080 + 526.83*d
	938 ft < d < 1,328 ft:	NEWQD = 60,778 + 255.83*d
	ft: d > 1,328 ft	$NEWQD = d^3/5,832$
	Metric EQNs (NEWQD in kg, d in m)	
	NEWQD < 45,359 kg:	*$d = 4.76 * NEWQD^{1/3}$*
	45,359 kg < NEWQD < 136,077 kg:	*$d = (4.5704 + 1.7420 \times 10^{-6} * NEWQD + 4.0389 \times 10^{-11} * NEWQD^2) * NEWQD^{1/3}$*
	136,077 kg < NEWQD < 181,436 kg:	*$d = (0.7692 + 3.5182 \times 10\text{-}5 * NEWQD) * NEWQD^{1/3}$*
	NEWQD > 181,436 kg:	*$d = 7.14 * NEWQD^{1/3}$*
	d < 169.8 m:	*$NEWQD = d^3/107.877$*
	169.8 m < d < 285.7 m:	*NEWQD = -87,578 + 784.00*d*
	285.7 m < d < 404.7 m:	*NEWQD = 27,568 + 380.7*d*
	d > 404.7 m:	*$NEWQD = d^3/364.086$*

5.32.4 IMD for magazines with Hazard Division 1.1 shall be separated one from another in accordance with Table 5-12, 5-13 and 5-14. Table 5-12 provides orientation relationships for ECMs and Table 5-13 and 5-14 provide the actual separation distances in accordance to the following considerations:

a. When ECM containing Hazard Division 1.1 explosives are sited so that any one is in the forward sector of another, the two shall be separated by distances greater than the minimum permitted for side-to-side orientations. The forward sector, or "front," of an ECM is that area 60° either side of the magazine centerline (120° combined angle) with the vertex of the angle placed so that the sides of the angle pass through the intersection of the headwall and sidewalls (See Figure 5-4). The greater distances are required primarily for the protection of door and headwall structures against blast from a PES forward of the exposed magazine, and to a lesser extent due to the directionality of effects from the source. The rear sector, or "rear," of an ECM is that area 45° either side of the magazine centerline (90° combined angle) with the vertex of the angle placed so that the sides of the angle pass through the intersection of the rear and side walls. Figure 5-5 illustrates the front (120°), side, and rear (90°) sectors of an ECM. When a blast wave is reflected from a surface at other than grazing

incidence (side-on-orientation), the overpressure may be increased substantially over the free-field value. High reflected pressure and impulse can damage doors and headwalls and propel the debris into the ECM so that explosion is communicated by impact of such debris upon the contents.

b. Examples of siting rules relative to magazine orientations (illustrated in Figure 5-4) follow:

(1) See Figure 4(a) and (b). Site A as a side-to-side ES. Site B as side-to-side ES. Orientations are to be thought of as from the PES to the ES.

(2) See Figure 5-4(c). Site A as a side-to-front ES. Site B as a front-to-side ES.

Table 5-12. Hazard Division 1.1 Intermagazine Hazard Factors

To ES		From PES									
		ECM[a]				AGM *or Aboveground Operating Building*[b]		Modules and/or Cells		HPM[c, d]	
		S	R	FB	FU	B	U	B	U	S	F[e]
		(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
		[m/kg$^{1/3}$]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
ECM (7-Bar)	S	1.25	1.25	2.75	2.75	4.5	4.5	4.5	4.5	1.25	2.75
		0.50	*0.50*	*1.09*	*1.09*	*1.79*	*1.79*	*1.79*	*1.79*	*0.50*	*1.09*
	R	1.25	1.25	2	2	4.5	4.5	4.5	4.5	1.25	2
		0.50	*0.50*	*0.79*	*0.79*	*1.79*	*1.79*	*1.79*	*1.79*	*0.50*	*0.79*
	FU	2.75	2	6	6	6	6	6	6	2.75	6
		1.09	*0.79*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*1.09*	*2.38*
	FB[f]	2.75	2	4.5	6	4.5	6	4.5	6	2.75	6
		1.09	*0.79*	*1.79*	*2.38*	*1.79*	*2.38*	*1.79*	*2.38*	*1.09*	*2.38*
ECM (3-Bar)	S	1.25	1.25	2.75	2.75	6	6	6	6	1.25	2.75
		0.50	*0.50*	*1.09*	*1.09*	*2.38*	*2.38*	*2.38*	*2.38*	*0.50*	*1.09*
	R	1.25	1.25	2	2	6	6	6	6	1.25	2
		0.50	*0.50*	*0.79*	*0.79*	*2.38*	*2.38*	*2.38*	*2.38*	*0.50*	*0.79*
	FU	4.5	4.5	6	9	6	9	6	9	4.5	9
		1.79	*1.79*	*2.38*	*3.57*	*2.38*	*3.57*	*2.38*	*3.57*	*1.79*	*3.57*
	FB[f]	4.5	4.5	6	6	6	6	6	6	4.5	6
		1.79	*1.79*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*1.79*	*2.38*
ECM (Undefined)	S	1.25[g]	1.25[g]	4.5[g]	4.5[g]	6	6	6	6	1.25	4.5
		0.50[g]	*0.50[g]*	*1.79[g]*	*1.79[g]*	*2.38*	*2.38*	*2.38*	*2.38*	*0.50*	*1.79*
		2[h]	2[h]	6[h]	6[h]						
		0.79[h]	*0.79[h]*	*2.38[h]*	*2.38[h]*						
	R	1.25	1.25	2	2	6	6	6	6	1.25	2
		0.50	*0.50*	*0.79*	*0.79*	*2.38*	*2.38*	*2.38*	*2.38*	*0.50*	*0.79*
	FU	6	6	6	11	6	11	6	11	6	11
		2.38	*2.38*	*2.38*	*4.36*	*2.38*	*4.36*	*2.38*	*4.36*	*2.38*	*4.36*
	FB[f]	6	6	6	6	6	6	6	6	6	6
		2.38	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*
	U	6	6	6	11	6	11	6	11	6	11
		2.38	*2.38*	*2.38*	*4.36*	*2.38*	*4.36*	*2.38*	*4.36*	*2.38*	*4.36*

To ES		From PES									
		ECM[a]				AGM *or Aboveground Operating Building*[b]		Modules and/or Cells		HPM[c, d]	
		S	R	FB	FU	B	U	B	U	S	F[e]
		(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
		[m/kg$^{1/3}$]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
AGM	B	6	6	6	6	6	6	6	6	6	6
		2.38	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*	*2.38*
Modules and/or Cells	U	6	6	6	11	6	11	1.1[i]	11[i]	6	11
		2.38	*2.38*	*2.38*	*4.36*	*2.38*	*4.36*	*0.44*[i]	*4.36*	*2.38*	*4.36*
	B	1.25	1.25	6	6	6	6	1.1[i]	1.1[i]	1.25	6
		0.50	*0.50*	*2.38*	*2.38*	*2.38*	*2.38*	*0.44*[i]	*0.44*[i]	*0.50*	*2.38*
HPM	S,F[d]	1.25	1.25	2.75	2.75	4.5	4.5	4.5	4.5	1.25	2.75
		0.50	*0.50*	*1.09*	*1.09*	*1.79*	*1.79*	*1.79*	*1.79*	*0.50*	*1.09*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

S = Side; R = Rear; F = Front; B = Barricaded; U = Unbarricaded; FU = Front Unbarricaded; FB = Front Barricaded; ECM = Earth-Covered Magazine (7-Bar, 3-Bar, or Undefined, which refers to the structural strength of the headwall and door(s)); AGM = Aboveground Magazine; HPM = High Performance Magazine; PES = Potential Explosion Site; ES – Exposed Site	
a	Descriptions of ECM are in section DDESB TP15.
b	AGM are all types of above grade (non-earth-covered) magazines or storage pads.
c	A description of an HPM can be found at section DDESB TP15. The MCE in an HPM is limited to a maximum of 60,000 lbs [27,216 kg].
d	The storage areas in the HPM are barricaded on all sides and protected by a reinforced concrete cover. All directions are, therefore, considered to be Side (S) orientations when it is the ES. For siting purposes, an HPM has no Rear (R) sector.
e	The unbarricaded front (entrance to loading area) is a factor when the HPM is the PES because the MCE includes explosives in the loading area. The hazard factors have been determined accordingly.
f	Those barricades serve to mitigate both fragments and overpressure hazards.
g	Use this K-factor for NEWQD in PES up to 250,000 lbs [113,398 kg].
h	Use this K-factor for NEWQD in PES greater than 250,000 lbs [113,398 kg].
i	Modules and/or cells are defined in section V2.E5.6 of DOD 6055.09

(3) See Figure 5-4(d). Site each magazine as a front-to-front ES. Site C as a barricaded ES. Site A and B as unbarricaded ESs.

(4) Two additional ECM orientations warrant analysis, namely:

(a) See Figure 5-4(e). Site A as a side-to-front ES. Site B as a front-to-side ES.

(b) See Figure 5-4(f). Site A as a side-to-front ES. Site B as a front-to-side ES.

c. Barricaded IMD from ECM. Criteria is provided below for the application of barricaded IMD from ECM.

d. Other factors limiting an ECM storage area are:

(1) Quantities above 500,000 lbs. NEW of Hazard Division 1.1 shall not be stored in any one storage location, except for energetic liquids.

(2) The distances given in Table 5-13 and 5-14 for 100 lbs. NEW of Hazard Division 1.1 shall constitute the minimum required magazine spacing.

e. Application of Barricaded ILD and Barricaded IMD from an ECM. Figure 5-5 illustrates the intermagazine relationships that can exist between an ECM and aboveground magazine and the intraline relationships that can exist between an ECM and a facility permitted to be at ILD or barricaded ILD from an ECM, when each contain HD 1.1 explosives. Permissible ILD and barricaded ILD exposures are provided in section 5.30.3. Siting criteria for aboveground magazines are provided in Table 5-13 and 5-14. The unbarricaded IMD or ILD, as applicable, shall apply to ECMs except as provided below.

(1) Front (120°) Sector of an ECM: Barricaded ILD or barricaded IMD, as applicable, may be applied from an ECM to an ES located within the ECM's 120° front sector, provided that an intervening barricade meets the requirements of the construction criteria.

(2) Side and Rear (90°) Sectors of an ECM: Barricaded ILD or barricaded IMD, as applicable, may be applied if an ECM's earth cover meets construction criteria of DDESB TP15, it then qualifies as a barricade.

f. Existing ECM, regardless of orientation, meeting the construction and barricading requirements of DDESB TP15 (and sited one from another for a minimum of 100 pounds NEW of Hazard Division 1.1), may be used to their physical capacity for the storage of Hazard Divisions 1.2, 1.3, and 1.4 provided distances to other exposures comply with applicable QD tables.

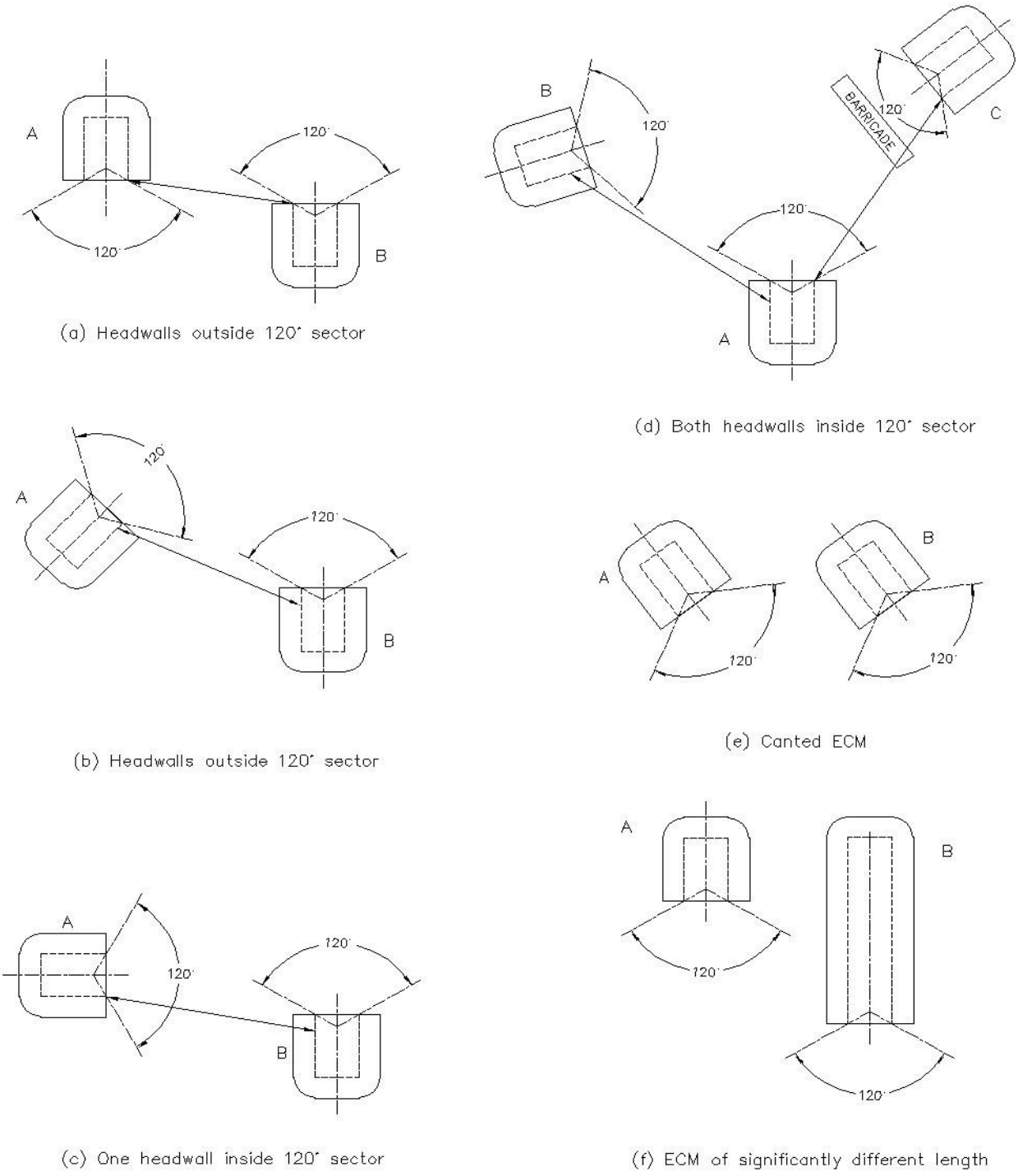

Figure 5-2. Orientation Effects on Intermagazine Distance

(Reference: DoD 6055.09, March 12, 2012)

NOTES: See Table 5-12 for applicable separation distances between ECM.

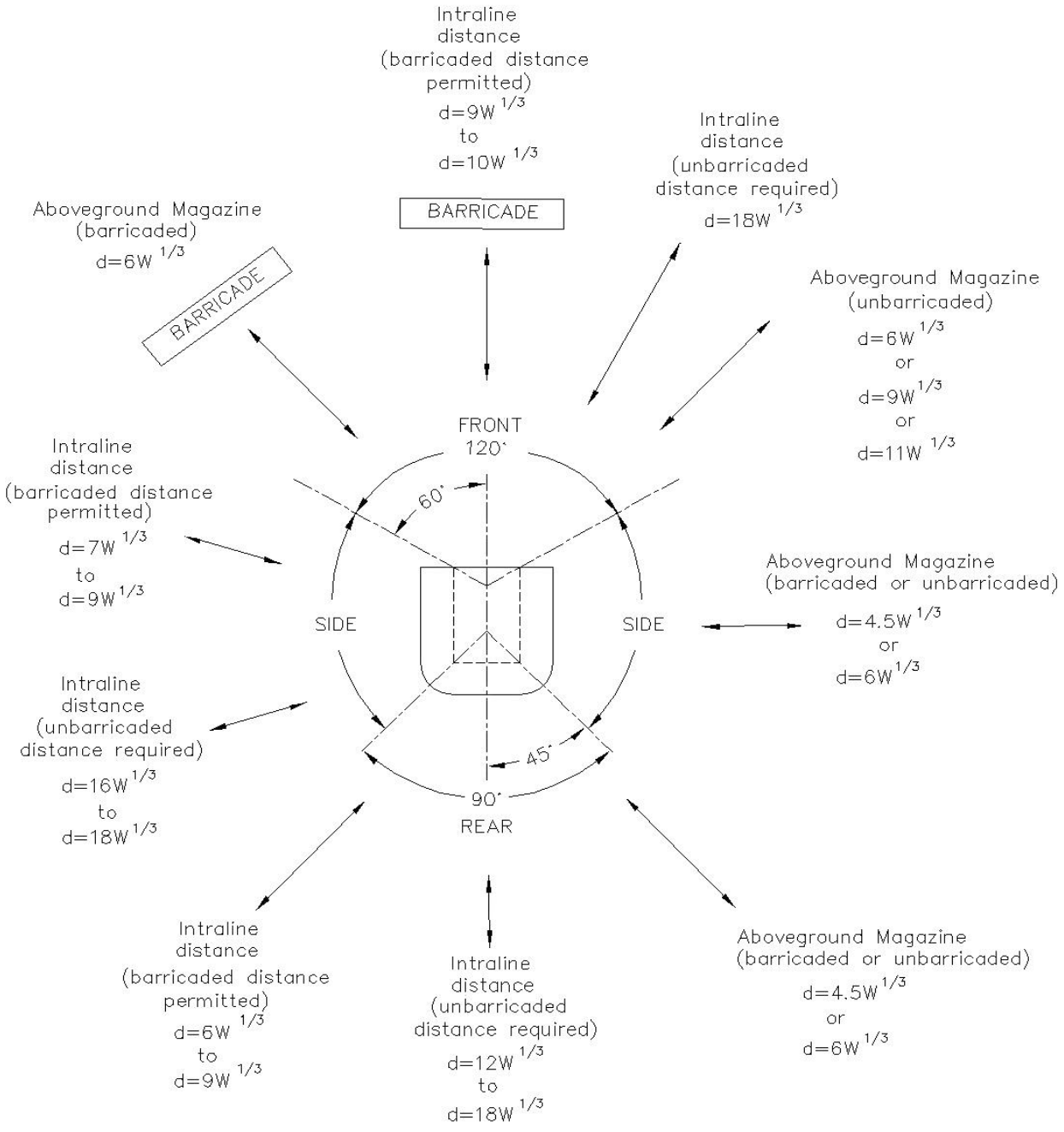

Figure 5-3. Orientation Effects on Interline Distance

(Reference: DoD 6055.09, March 12, 2012)

NOTES: See 5.35.3 for application of ILD and barricaded ILD from an ECM, application of barricaded ILD and barricaded IMD from an ECM and permissible intraline and barricaded intraline exposures.

Table 5-13. Intermagazine Hazard Factors and Distances for Hazard Division 1.1 for K = 1.1, 1.25, 2, 2.75, 4.5, and 5

NEWQD	Hazard Factor, K					
	1.1	1.25	2	2.75	4.5	5
	0.44	*0.5*	*0.79*	*1.09*	*1.79*	*1.98*
(lbs)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
[kg]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
100	7	7	9.3	13	21	23
45.4	*2.1*	*2.1*	*2.8*	*3.9*	*6.4*	*7.1*
150	7	7	11	15	24	27
68	*2.1*	*2.1*	*3.2*	*4.4*	*7.3*	*8.1*
200	7	7.3	12	16	26	29
90.7	*2.1*	*2.2*	*3.5*	*4.9*	*8*	*8.9*
300	7.4	8.4	13	18	30	33
136.1	*2.3*	*2.6*	*4.1*	*5.6*	*9.2*	*10.2*
500	8.7	9.9	16	22	36	40
226.8	*2.7*	*3*	*4.8*	*6.6*	*10.9*	*12.1*
700	9.8	11	18	24	40	44
317.5	*3*	*3.4*	*5.4*	*7.4*	*12.2*	*13.5*
1000	11	13	20	27	45	50
453.6	*3.4*	*3.8*	*6.1*	*8.4*	*13.8*	*15.2*
1500	13	14	23	31	52	57
680.4	*3.9*	*4.4*	*6.9*	*9.6*	*15.7*	*17.4*
2000	14	16	25	35	57	63
907.2	*4.3*	*4.8*	*7.6*	*10.6*	*17.3*	*19.2*
3000	16	18	29	40	65	72
1360.8	*4.9*	*5.5*	*8.8*	*12.1*	*19.8*	*21.9*
5000	19	21	34	47	77	85
2268	*5.8*	*6.6*	*10.4*	*14.3*	*23.5*	*26*
7000	21	24	38	53	86	96
3175.1	*6.5*	*7.3*	*11.6*	*16*	*26.3*	*29.1*
10000	24	27	43	59	97	108
4535.9	*7.3*	*8.3*	*13.1*	*18*	*29.6*	*32.8*
15000	27	31	49	68	111	123
6803.9	*8.3*	*9.5*	*15*	*20.7*	*33.9*	*37.5*
20000	30	34	54	75	122	136
9071.8	*9.2*	*10.4*	*16.5*	*22.7*	*37.3*	*41.3*
30000	34	39	62	85	140	155
13607.7	*10.5*	*11.9*	*18.9*	*26*	*42.7*	*47.3*
50000	41	46	74	101	166	184
22679.5	*12.5*	*14.2*	*22.4*	*30.9*	*50.7*	*56*
70000	45	52	82	113	185	206
31751.3	*13.9*	*15.8*	*25*	*34.5*	*56.7*	*62.7*

NEWQD	Hazard Factor, K					
	1.1	1.25	2	2.75	4.5	5
	0.44	*0.5*	*0.79*	*1.09*	*1.79*	*1.98*
(lbs)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
[kg]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
100000	51	58	93	128	209	232
45359	*15.7*	*17.8*	*28.2*	*38.9*	*63.8*	*70.6*
150000	58	66	106	146	239	266
68038.5	*18*	*20.4*	*32.3*	*44.5*	*73.1*	*80.8*
200000	64	73	117	161	263	292
90718	*19.8*	*22.5*	*35.5*	*49*	*80.4*	*89*
300000	74	84	134	184	301	335
136077	*22.6*	*25.7*	*40.6*	*56.1*	*92.1*	*101.8*
500000	87	99	159	218	357	397
226795	*26.8*	*30.5*	*48.2*	*66.5*	*109.2*	*120.7*
700000	98	111	178	244	400	444
317513	*30*	*34.1*	*53.9*	*74.4*	*122.1*	*135.1*
1000000	110	125	200	275	450	500
453590	*33.8*	*38.4*	*60.7*	*83.7*	*137.5*	*152.1*

(Reference: DoD 6055.09, March 12, 2012)

Table 5-14. Intermagazine Hazard Factors and Distances for Hazard Division 1.1 for K = 6, 8, 9, 11, 18 and 40

NEWQD	Hazard Factor, K					
	6	8	9	11	18	40
	2.38	*3.17*	*3.57*	*4.36*	*7.14*	*15.87*
(lbs)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
[kg]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
100	28	37	42	51	84	186
45.4	*8.5*	*11.3*	*12.7*	*15.5*	*25.5*	*56.6*
150	32	43	48	58	96	213
68	*9.7*	*12.9*	*14.6*	*17.8*	*29.1*	*64.8*
200	35	47	53	64	105	234
90.7	*10.7*	*14.2*	*16*	*19.6*	*32.1*	*71.3*
300	40	54	60	74	120	268
136.1	*12.2*	*16.3*	*18.4*	*22.4*	*36.7*	*81.6*
500	48	63	71	87	143	317
226.8	*14.5*	*19.3*	*21.8*	*26.6*	*43.5*	*96.8*
700	53	71	80	98	160	355
317.5	*16.2*	*21.6*	*24.4*	*29.7*	*48.7*	*108.3*
1000	60	80	90	110	180	400
453.6	*18.3*	*24.4*	*27.4*	*33.5*	*54.9*	*121.9*
1500	69	92	103	126	206	458

NEWQD	Hazard Factor, K					
	6	8	9	11	18	40
	2.38	*3.17*	*3.57*	*4.36*	*7.14*	*15.87*
(lbs)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)	(ft/lb$^{1/3}$)
[kg]	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*	*[m/kg$^{1/3}$]*
680.4	*20.9*	*27.9*	*31.4*	*38.3*	*62.8*	*139.6*
2000	76	101	113	139	227	504
907.2	*23*	*30.7*	*34.6*	*42.2*	*69.1*	*153.6*
3000	87	115	130	159	260	577
1360.8	*26.4*	*35.1*	*39.6*	*48.3*	*79.1*	*175.9*
5000	103	137	154	188	308	684
2268	*31.3*	*41.6*	*46.9*	*57.3*	*93.8*	*208.5*
7000	115	153	172	210	344	765
3175.1	*35*	*46.6*	*52.5*	*64.1*	*104.9*	*233.3*
10000	129	172	194	237	388	862
4535.9	*39.4*	*52.5*	*59.1*	*72.2*	*118.2*	*262.7*
15000	148	197	222	271	444	986
6803.9	*45.1*	*60.1*	*67.6*	*82.6*	*135.3*	*300.7*
20000	163	217	244	299	489	1086
9071.8	*49.6*	*66.1*	*74.5*	*90.9*	*148.9*	*331*
30000	186	249	280	342	559	1243
13607.7	*56.8*	*75.7*	*85.2*	*104.1*	*170.5*	*378.9*
50000	221	295	332	405	663	1474
22679.5	*67.4*	*89.7*	*101.1*	*123.4*	*202.1*	*449.2*
70000	247	330	371	453	742	1649
31751.3	*75.4*	*100.4*	*113*	*138.1*	*226.1*	*502.5*
100000	278	371	418	511	835	1857
45359	*84.9*	*113.1*	*127.3*	*155.5*	*254.6*	*566*
150000	319	425	478	584	956	2125
68038.5	*97.2*	*129.4*	*145.7*	*178*	*291.5*	*647.9*
200000	351	468	526	643	1053	2339
90718	*106.9*	*142.4*	*160.4*	*195.9*	*320.8*	*713.1*
300000	402	536	602	736	1205	2678
136077	*122.4*	*163.1*	*183.6*	*224.3*	*367.2*	*816.3*
500000	476	635	714	873	1429	3175
226795	*145.1*	*193.3*	*217.7*	*265.9*	*435.4*	*967.8*
700000	533	710	799	977	1598	3552
317513	*162.4*	*216.3*	*243.6*	*297.4*	*487.1*	*1082.7*
1000000	600	800	900	1100	1800	4000
453590	*182.9*	*243.6*	*274.3*	*335*	*548.6*	*1219.4*

(Reference: DoD 6055.09, March 12, 2012)

5.32.5 Minimum Fragment Distances.

a. Minimum primary fragment distances are to protect personnel in the open; minimum firebrand distances are to protect facilities. Since firebrands are burning fragments with the potential to ignite other sites or facilities, the firebrands and fragments have the same distance, which shall be applied to:

(1) Center boundaries, unless manifestly inapplicable (e.g., unsuitable terrain, government land not open to the public). For locations where Center boundary lines are penetrated by inhabited building QD arcs, the Center shall certify that conditions do not exist for the application of inhabited building protection to the encumbered area and establish procedures to monitor the area for any change in that status.

(2) Administration and housing areas.

(3) Athletic and other recreation areas except as described below.

(4) Flight line passenger service functions.

(5) Main powerhouses providing vital utilities to a major portion of the Center.

(6) Storehouses and shops that, by reason of their vital, strategic nature, or the high intrinsic value of their contents, should not be placed at risk.

(7) Functions that, if momentarily put out of action, would cause an immediate secondary hazard by reason of their failure to function.

(8) Private vehicles parked in administrative areas.

5.32.5.1 Examples when minimum fragment and firebrand distances need not be applied are:

a. Recreation or training facilities if these facilities are for the exclusive use of personnel assigned to the PES.

b. Related and NASA controlled support functions for which intermagazine and ILDs are the usual protection levels.

c. Maintenance, supply, and training facilities, and operations offices for the service of the logistics and operations functions of aircraft carrying explosives.

d. Between PES and relatively static inert storage areas, including parking areas for dead storage of government aircraft or vehicles.

e. Between facilities in an operating line; between operating lines; and between operating lines and storage locations that normally are separated by IBDs to protect workers and ensure against interruption of production.

5.32.5.2 The minimum distance for protection from hazardous fragments shall be based on primary and secondary fragments from the PES and the population and/or traffic density of the ES. It is defined as the distance at which the density of hazardous fragments becomes 1 per 600 ft^2.

5.32.5.2.1 For populous locations, where government, contractor employees, dependent, and/or public personnel are located, the minimum distance shall be that distance at which fragments, including debris from structural elements of the facility or process equipment, do not exceed a hazardous fragment density of one hazardous fragment per 600 ft^2 (56 m^2). If this distance is not known, the following shall apply

Note: This distance is not the maximum fragment range. Secondary fragments include debris such as that from structural elements of the facility and from non-confining process equipment likely to rupture into enough pieces to significantly contribute to the total number of expected fragments. Analyses and/or tests approved by the Chief, SMA may be used to determine minimal distances for both primary and secondary fragments. DDESB Technical Paper No. 13 is an example of a method to determine minimal distances for building debris, while U.S. Army Corps of Engineers Reports HNC-ED-CS-98-1 and 98-2 provide similar information for primary fragments. In the absence of appropriate analyses and/or tests, default hazardous debris distances defined below apply.

a. For all types of Hazard Division 1.1 in quantities $\leq$ 450 lbs. NEW, the hazardous fragment distance (HFD), which equates to IBD, shall be determined as follows:

(1) For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, use "ECM" distances shown in Table 5-9 as discussed in section 5.32.1. Intraline criteria shall be in accordance with section 5. 2.3.2.

(2) For Hazard Division 1.1 in an Undefined ECM, where the loading density [NEW (lbs.)/internal magazine volume (ft3)] is < 0.028 lbs. /ft3, use "ECM" distances shown in Table 5-9, as discussed in section 5.32.1. Intraline criteria shall be in accordance with section 5.2.3.2.

(3) For Hazard Division 1.1 in an Undefined ECM where the loading density is > 0.028 lbs./ft^3, use "ECM - Side and Rear" distances of Table 5-9 and for front exposure, apply the greater of "ECM - Front" IBD distance of Table 5-9 or the HFD from the “Structure” column of Table 5-15 for the NEW in the ECM; if the ECM headwall meets the definition of aboveground structure or site (AGS) heavy wall (H) use the “Structure” column of Table 5-15, otherwise, use the “Structure” column for nonprimary fragment producing explosives or the “Open” column for primary fragment producing explosives. PTRD is 60% of IBD or HFD, as applicable. Intraline criteria shall be in accordance with section 5.2.3.2.

(4) Where ECM, regardless of structural designation, have been designed, analyzed, or tested to have a reduced IBD and have been approved by NASA Headquarters, Chief, SMA use the approved IBD. PTRD is 60% of IBD. Intraline criteria shall be in accordance with section 5.2.3.2.

Table 5-15. Hazard Division 1.1 Hazardous Fragment Distances[a,b]

NEWQD	Open[c, d]	Structure[e, f]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
≤ 0.5	236	200
< 0.23	*71.9*	*61.0*
0.7	263	200
0.3	*80.2*	*61.0*
1	291	200
0.45	*88.8*	*61.0*
2	346	200
0.91	*105.5*	*61.0*
3	378	200
1.4	*115.3*	*61.0*
5	419	200
2.3	*127.7*	*61.0*
7	445	200
3.2	*135.6*	*61.0*
10	474	200
4.5	*144.4*	*61.0*
15	506	200
6.8	*154.2*	*61.0*
20	529	200
9.1	*161.1*	*61.0*
30	561	200
13.6	*170.9*	*61.0*
31	*563.0*	200
14.1	*171.7*	*61.0*
50	601	388
22.7	*183.2*	*118.2*
70	628	519
31.8	*191.3*	*158.1*
100	658	658
45.4	*200.4*	*200.4*
150	815	815
68.0	*248.5*	*248.5*
200	927	927
90.7	*282.6*	*282.6*
300	1,085	1,085
136.1	*330.6*	*330.6*
450	1,243	1,243
204.1	*378.7*	*378.7*
> 450	1,250	1,250
>204.1	*381.0*	*381.0*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Use of equations given in footnotes c through f, to determine other HFD-NEWQD combinations, is allowed.
b	PTRD is 60% of HFD.
c	English EQNs (NEWQD in lbs, HFD in ft; ln is natural logarithm) NEWQD < 100 lbs: HFD = 291.3 + [79.2*ln(NEWQD)], with a minimum distance of 236 ft NEWQD ≥ 100 lbs: HFD = -1133.9 + [389*ln(NEWQD)] *Metric EQNs (NEWQD in kg, HFD in m; ln is natural logarithm)* *NEWQD < 45.4 kg: HFD = 107.87 + [24.14*ln(NEWQD)], with a minimum distance of 71.9 m* *NEWQD > 45.4 kg: HFD = -251.87 + [118.56*ln(NEWQD)]*
d	English EQNs (NEWQD in lbs, HFD in ft; exp [x] is e^x) HFD < 658 ft: NEWQD = exp [(HFD/79.2) – 3.678] 658 ft ≤ HFD < 1,250 ft: NEWQD = exp [(HFD/389) + 2.914] *Metric EQNs (NEWQD in kg, HFD in m;* exp [x] is e^x*)* *HFD < 200.5 m: NEWQD = exp [(HFD/24.14) – 4.4685]* *200.5 m < HFD < 381 m: NEWQD = exp [(HFD/118.56) + 2.1244]*
e	English EQNs (NEWQD in lbs, HFD in ft; ln is natural logarithm) NEWQD ≤ 31 lbs: HFD = 200 ft 31 lbs < NEWQD ≤ 450 lbs: HFD = -1133.9 + [389*ln(NEWQD)] *Metric EQNs (NEWQD in kg, HFD in m; ln is natural logarithm)* *NEWQD ≤ 14.1 kg: HFD = 61.0 m* *14.1 kg < NEWQD < 204.1 kg: HFD = -251.87 + [118.56*ln(NEWQD)]*
f	English EQNs (NEWQD in lbs, HFD in ft; exp [x] is e^x) HFD ≤ 200 ft: NEWQD ≤ 31 lbs 200 ft < HFD ≤ 1,250 ft: NEWQD = exp [(HFD/389) + 2.914] *Metric EQNs (NEWQD in kg, HFD in m;* exp [x] is e^x*)* *HFD ≤ 61.0 m: NEWQD ≤ 14.1 kg* *61.0 m < HFD < 381.0 m: NEWQD = exp [(HFD/118.56) + 2.2144]*

(5) For Hazard Division 1.1 in a structure (excluding ECM) capable of stopping primary fragments, but which can contribute to the debris hazard, use the HFD listed in the "Structures" column of Table 5-15. Intraline criteria shall be in accordance with section 5.2.3.2.

(6) Structures that are capable of stopping primary fragments include all heavy wall (H) and heavy wall/roof (H/R) aboveground sites (AGS), as defined in the Legend for Table 5-19. Doors and other openings through which primary fragments could exit shall be capable of stopping primary fragments from exiting the facility or shall be barricaded in order to trap primary fragments that could exit the facility.

(7) For Hazard Division 1.1 in the open or in a structure incapable of stopping primary fragments, use HFD listed in the "Open" column of Table 5-15. Intraline criteria shall be in accordance with section 5.2.3.2. Structures (other than ECM) that are capable of stopping primary fragments include all heavy wall (H) and heavy wall/roof (H/R) aboveground sites (AGS), as defined in the Legend for Table 5-19. All other structures (other than ECM) are considered incapable of stopping primary fragments. PTRD is 60% of HFD.

(8) For bare explosives in the open, distance is computed by the formula $d=40W^{1/3}$.

b. For Hazard Division 1.1 NEWs in the range 451 to 30,000 lbs., HFD shall be determined according to the below criteria. PTRD is 60% of the HFD, and intraline criteria, as applicable, shall be in accordance with section 5.2.3.2

(1) The minimum HFD shall be 1250 ft., as shown in Table 5-9. Lesser distances are permitted if supported by a structural analysis. Existing facilities sited at 1,235 ft. or 1,245 ft. per past standards may be considered to be in compliance with the 1,250 ft. minimum requirement.

(2) For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, use "ECM" distances shown in Table 5-9.

(3) For Hazard Division 1.1 in an Undefined ECM, where the loading density is $\leq$ 0.028 lbs./ft^3, use "ECM" distances shown in Table 5-9.

(4) For Hazard Division 1.1 in an Undefined ECM with minimum internal dimensions of 26 feet wide by 60 ft. long, use "ECM - side and rear" distances of Table 5-9 and "Other PES" distance of Table 5-9 for the front exposure.

(5) For Hazard Division 1.1 in an Undefined ECM where the loading density is > 0.028 lbs./ft^3 and internal dimensions are less than 26 feet wide by 60 ft. long, use "Other PES" distances of Table 5-9 for front, side, and rear exposures.

(6) For bare explosives in the open, distance is computed by the formula $d=40W^{1/3}$.

c. For Hazard Division 1.1 NEWs > 30,000 lbs., HFD shall be in accordance with Table 5-9. Lesser distances are permitted if supported by a structural analysis. PTRD is 60% of HFD and intraline criteria, as applicable, shall be in accordance with Section 5.2.3.2. The following apply to use of the reduced "ECM" distances shown in Table 5-9 for the NEW range between 30,000 lbs. and 250,000 lbs.:

(1) For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, where internal dimensions are a minimum of 26 feet wide by 60 ft. long, use "ECM" distances shown in Table 5-9.

(2) For Hazard Division 1.1 in a 7-Bar or a 3-Bar ECM, where internal dimensions are less than 26 feet wide by 60 ft. long, use "Other PES" distances of Table 5-9 for front, side, and rear exposures.

5.32.5.3 For sparsely populated locations, the minimum 1,250 ft. fragment distance may be reduced to 900 ft. if certain specific conditions exist as follows:

a. No more than 25 persons are located in any sector bounded by the sides of a 45° angle, with the vertex at the PES, and the 900 ft. and 1,250 ft. arcs from the PES.

b. The NEW of the PES does not exceed 11,400 lbs.

5.32.5.4 For PTR, the minimum fragment and debris distance for Hazard Division 1.1 explosives shall be based on the traffic density considered at three levels: high traffic density, medium traffic density, and low traffic density, averaged over a normal (non-

holiday) week in terms of number of passengers during a 24-hour period. Minimum fragment distance reductions based on sparse population considerations do not apply to PTR.

Note: In applying criteria other than the default values for high, medium, and low traffic densities (which are based on car (and rail) speed of 50 miles/hour, and a ship speed of 10 mile/hour), considerations such as the following need to be taken into account to establish acceptable exposure: speed of vehicles, number of passengers per vehicle, protection afforded by the vehicle, variation in daily traffic levels in relation to explosives activities, and seasonal traffic trends. The default value of two passengers per car may be used to estimate traffic density.

a. High Traffic Density. IBD criteria apply.

b. Medium Traffic Density. 60% of the specified minimum fragment distance for IBD applies. Medium traffic density criteria for minimum fragment distance apply, as a minimum, to recreational activity that is extensive and occurs on a regular basis.

c. Low Traffic Density. Minimum distance shall be based on blast criteria (K24/K30) only. No minimum fragment distance is required.

d. For other exposures that are permitted at PTR separation distances, fragment and debris distance minima for Hazard Division 1.1 explosives shall be at least 60% of the specified minimum fragment distance for IBD.

5.32.6 Hazard Division 1.2.

5.32.6.1 The HD 1.2 hazard classification is given to items configured for storage and transportation that do not mass detonate when a single item or package in a stack is initiated. Explosions involving such items result in their burning and exploding progressively with no more than a few at a time reacting. These reactions will typically project fragments, firebrands, and unexploded items from the explosion site. Blast effects are limited to the immediate vicinity and are not the primary hazard.

5.32.6.2 Small quantities of HD 1.2.1 ($\leq$ 450 pounds NEW), in certain packaging configurations, react in a manner more typical of an HD 1.1 event. When located in structures that stop primary fragments, but which generate a secondary debris hazard (e.g., certain ECM and hardened structures), the structural damage and debris hazards produced from these events again are more characteristic of an HD 1.1 explosion, rather than the progressive nature of an HD 1.2.1 event, as described above. When the NEW and the MCE of the packaged HD 1.2.1 items fall within the ranges specified in equation {NEW $\leq$ MCE $\leq$ 450 lbs.}, the HD 1.2.1 shall be treated as HD 1.1. If they fall outside the ranges of the equation, then the criteria of Table 5-19 shall be applied.

5.32.6.3 The NEW of an HD 1.2 item (used for transportation) is the sum of the weight of the HD 1.1 and 1.3 material contained within the item. The NEWQD for an item is equal to NEW (NEWQD = NEW) unless testing has been conducted. Based on testing, the NEWQD may include a reduced contribution (less than or equal to 100 percent) from the HD 1.3 material as a result of the functioning of the HD 1.1 material. The NEWQD should be determined by the Single Package Test (United Nations (UN) Test 6 (a) or its equivalent), not the Bonfire Test (UN Test 6 (c)). The NEWQD for a specific item may be obtained from

the Joint Hazard Classification System (JHCS).The effects produced by the functioning of HD 1.2 items vary with the size and weight of the item. HD 1.2 explosives items are separated into two subdivisions in order to account for the differences in magnitude of these effects for purposes of setting QD criteria. The more hazardous items are referred to as HD 1.2.1 items and have an NEWQD greater than 1.60 pounds. The less hazardous items, referred to hereafter as HD 1.2.2, have an NEWQD less than or equal to 1.60 pounds. These two HD 1.2 subdivisions are shown below with their definitions:

HD 1.2.1: NEWQD > 1.60 pounds

HD 1.2.2: NEWQD $\leq$ 1.60 pounds

Note: It is important not to exaggerate the significance of the value of 1.60 pounds used above. It is based on a break point in the database supporting the QD relationships and tables and the NEWQD of the items tested. If comprehensive data are available for a particular item, then the item may be placed in that category of HD 1.2 supported by the data and allocated the relevant QD.

5.32.6.4 The MCE for HD 1.2.1 is the NEWQD of an item times the number of items in three un-palletized, outer shipping packages, unless testing or analogy demonstrates a different MCE.

5.32.6.5 The QD specified for HD 1.2 explosives achieve the desired degree of protection against immediate hazards from an incident. Events involving HD 1.2 items lob large amounts of unexploded rounds, components, and subassemblies, which remain hazardous after impact. Such items are likely to be more hazardous than in their original state because of possible damage to fuse safety devices or other features by heat and impact. Furthermore, it is impractical to specify QD's that allow for the maximum possible flight ranges of propulsive items.

5.32.6.6 Table 5-19 provides a summary matrix of all the appropriate IBDs , PTRDs, and ILDs separations for HD 1.2.1 and HD 1.2.2 explosives, for the various combinations of ESs and PESs. When HD 1.2.1 items are stored in structures which may contribute to the debris hazard, the IBD is determined by using the larger of the following two distances: either that given in Table 5-16 for the appropriate explosives weight (number of items x NEWQD) or that given in Table 5-17 for the appropriate MCE. The HSS specified in Table 5-17 equates to the IBD.

5.32.6.7 IMDs are dependent upon the types of structures acting as both the PES and the ES. Table 5-19 provides a matrix of all the appropriate separations for the various combinations of ES and PES.

5.32.6.8 PTRD in Table 5-16, 5-17, 5-18, and 5-19 give consideration to the transient nature of the exposure in the same manner as for HD 1.1. PTRD is computed as 60% of the IBD for items in this hazard division, with a minimum distance equal to the IMD given in Table 5-19 for light structures, open stacks, trucks, trailers, or rail cars. Such structures are designated as AGS (L) in Table 5-19.

5.32.6.9 ILD given in Table 5-16, 5-17, 5-18, and 5-19 take into account the progressive nature of explosions involving these items (normally resulting from fire spread), up to the magnitude of the MCE, and the ability to evacuate personnel from endangered areas before

the progression involves large numbers of items. Exposed structures may be extensively damaged by projections and delayed propagation of explosions may occur due to the ignition of combustibles by projections. ILD is computed as 36% of the IBD for items of this HD, with a minimum distance equal to the IMDs given in Table 5-19 for the applicable PES-ES combination.

Table 5-16. Hazard Subdivision 1.2.1 Quantity-Distances (IBD, PTRD, ILD) for Explosives with NEWQD > 1.60 Pounds [0.73 kg][a,b]

Explosive Weight[c]	IBD[d, e, f]	PTRD[g]	ILD[h]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
2	200	200	200
0.9	*61*	*61*	*61*
3	200	200	200
1.4	*61*	*61*	*61*
4	200	200	200
1.8	*61*	*61*	*61*
5	200	200	200
2.3	*61*	*61*	*61*
7	200	200	200
3.2	*61*	*61*	*61*
10	200	200	200
4.5	*61*	*61*	*61*
15	200	200	200
6.8	*61*	*61*	*61*
20	200	200	200
9.1	*61*	*61*	*61*
30	200	200	200
13.6	*61*	*61*	*61*
50	200	200	200
22.7	*61*	*61*	*61*
70	200	200	200
31.8	*61*	*61*	*61*
100	268	200	200
45.4	*81.7*	*61*	*61*
150	348	209	200
68	*106*	*63.6*	*61*
200	403	242	200
90.7	*123*	*73.8*	*61*
300	481	288	200
136.1	*146.5*	*87.9*	*61*
500	576	346	207
226.8	*175.5*	*105.3*	*63.2*

Explosive Weight[c]	IBD[d, e, f]	PTRD[g]	ILD[h]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
700	638	383	230
317.5	*194.3*	*116.6*	*70*
1000	702	421	253
453.6	*213.9*	*128.3*	*77*
1500	774	464	278
680.4	*235.8*	*141.5*	*84.9*
2000	824	494	296
907.2	*251*	*150.6*	*90.4*
3000	893	536	321
1361	*272.1*	*163.3*	*98*
5000	978	587	352
2268	*298.1*	*178.9*	*107.3*
7000	1033	620	372
3175	*314.8*	*188.9*	*113.3*
10000	1090	654	392
4536	*332.3*	*199.4*	*119.6*
15000	1154	692	415
6804	*351.7*	*211*	*126.6*
20000	1198	719	431
9072	*365.2*	*219.1*	*131.5*
30000	1260	756	453
13608	*383.9*	*230.3*	*138.2*
50000	1335	801	481
22680	*406.8*	*244.1*	*146.4*
70000	1383	830	498
31751	*421.5*	*252.9*	*151.7*
100000	1433	860	516
45359	*436.8*	*262.1*	*157.3*
150000	1489	893	536
68039	*453.8*	*272.3*	*163.4*
200000	1528	917	550
90718	*465.6*	*279.3*	*167.6*
300000	1581	949	569
136077	*481.8*	*289.1*	*173.5*
500000	1646	988	593
226795	*501.7*	*301*	*180.6*
>500,000	Footnote f	Footnote g	Footnote h
>226,795	*Footnote f*	*Footnote g*	*Footnote h*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	The QD criteria for HD 1.2.1 items are based on the hazards from primary fragments. When stored in structures that may contribute to the debris hazard (secondary fragments), the IBD for HD 1.2.1 items whose MCE is greater than 31 lbs [14.1 kg] is determined by using the larger of two distances: those given in this table for the appropriate explosive weight or those given in Table 5-17. for the appropriate MCE. Structures that may contribute to the debris hazard for storage of HD 1.2.1 AE include: (a) all ECM frontal exposures (side and rear exposures have fixed minimum distances for IBD); (b) all AGS, including heavy wall (H), heavy wall and roof (H/R), and light (L), unless data or analyses are provided to show that the structural debris contribution is less. Note that ILD and PTRD are based on 36% and 60%, respectively, of the applicable IBD as determined in this footnote with minimum distances of: ILD minimum distances are given in Table 5-19. for applicable PES-ES combinations and PTRD minimum distances are given in Table 5-19. for AGS (L).
b	See Table 5-19. for a summary of IMD and minimum distances for ILD and PTRD.
c	Explosive Weight = Number of Items*NEWQD.
d	English EQN (IBD in ft, NEWQD in lbs; ln is natural logarithm) 71 lbs < Explosive Weight: IBD = -735.186 + [237.559*(ln(Number of items*NEWQD))] – [4.274*(ln(Number of items*NEWQD))^2], with a minimum of 200 f *Metric EQN (IBD in m, NEWQD in kg; ln is natural logarithm)* *18.6 kg < Explosive Weight: IBD = -167.648 + [70.345*(ln(Number of We items*NEWQD))] – [1.303*(ln(Number of items*NEWQD))^2], with a minimum of 61.0 m*
e	English EQN (IBD in ft, NEWQD in lbs; exp [x] is e^x) 200 ft < IBD < 2,016 ft: Number of items*NEWQD = exp [27.791 – (600.392 – 0.234*IBD)$^{1/2}$] *Metric EQN (IBD in m, NEWQD in kg; exp [x] is e^x)* *61.0 m < IBD < 614.5 m: Number of items*NEWQD = exp [27.000 – (600.287 – 0.768*IBD)$^{1/2}$]*
f	Use of equations given in Footnotes d and e to determine other IBD-weight combinations is allowed.
g	PTRD = 60% of IBD with a minimum distance equal to the IMD given in Table 5-19. for AGS (L). For other structures as either ES or PES, see Table 5-19.
h	ILD = 36% of IBD with a minimum distance equal to the IMD given in Table 5-19. for the applicable PES-ES combination. For structures other than AGS (L) as either ES or PES, see Table 5-19.

Table 5-17. Hazardous Debris Distances for HD 1.2.1 Items Stored in Structures Which Can Contribute to the Debris Hazard[a,b]

MCE	HDD[c, d, e]	PTRD[f]	ILD[g]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
≤ 31	200	200	200
≤14.1	*61.0*	*61.0*	*61.0*
50	388	233	200
22.7	*118.2*	*70.9*	*61.0*
70	519	311	200

MCE	HDD[c, d, e]	PTRD[f]	ILD[g]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
31.8	*158.1*	*94.9*	*61.0*
100	658	395	237
45.4	*200.4*	*120.2*	*72.1*
150	815	489	293
68.0	*248.5*	*149.1*	*89.4*
200	927	556	334
90.7	*282.6*	*169.5*	*101.7*
300	1,085	651	391
136.1	*330.6*	*198.4*	*119.0*
400	1,197	718	431
181.4	*364.7*	*218.8*	*131.3*
450	1,243	746	447
204.1	*378.7*	*227.2*	*136.3*
>450	1,250	750	450
>204.1	*381.0*	*228.6*	*137.2*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	The QD criteria for HD 1.2.1 items are based on the hazards from primary fragments. When stored in structures that may contribute to the debris hazard (secondary fragments), the IBD for HD 1.2.1 items whose MCE is greater than 31 lbs [14.1 kg] is determined by using the larger of two distances: those given in Table 5-16 for the appropriate explosive weight or those given in this table for the appropriate MCE. Structures that may contribute to the debris hazard for storage of HD 1.2.1 explosives include: (a) all ECM frontal exposures (side and rear exposures have fixed minimum distances for IBD); (b) all AGS, including H, H/R, and L, unless data or analyses are provided to show that the structural debris contribution is less. Note that ILD and PTRD are based on 36% and 60% respectively, of the applicable IBD as determined in this footnote with these minimum distances: ILD minimum distances as given in Table 5-19. for applicable PES-ES combinations, and PTRD minimum distances as given in Table 5-19. for AGS (L).
b	See Table 5-19. for a summary of IMD and minimum distances for ILD and PTRD.
c	English EQN (MCE in lbs, HDD in ft; ln is natural logarithm) 31 lbs < MCE ≤ 450 lbs: HDD = -1,133.9 + [389*ln(MCE)], with a minimum distance of 200 ft *Metric EQN (MCE in kg, HDD in m; ln is natural logarithm)* *14.1 kg < MCE ≤ 204 kg: HDD = -251.87 + [118.56*ln(MCE)],with a minimum distance of 61 m*
d	English EQN (MCE in lbs, HDD in ft; exp [x] is e^x) 200 ft < HDD ≤ 1,250 ft: MCE = exp [(HDD/389) + 2.914] *Metric EQN (MCE in kg, HDD in m; exp [x] is e^x)* *61.0 m < HDD < 381 m: MCE = exp [(HDD/118.56) + 2.1244]*
e	Use of equations given in footnotes c and d to determine other HDD-MCE combinations is allowed.
f	PTRD = 60% of IBD with a minimum distance equal to the IMD given in Table 5-19. for AGS (L). For other structures as either ES or PES, see Table 5-19.

g	ILD = 36% of IBD with a minimum distance equal to the IMD given in Table 5-19. for the applicable PES-ES combination. For structures other than AGS (L) as either ES or PES, see Table 5-19.

Table 5-18. Hazard Subdivision 1.2.2 Quantity-Distances (IBD, PTRD, ILD) for Explosives with NEWQD < 1.60 Pounds [0.73 kg][a,b,c]

Explosive Weight[d]	IBD[e, f, g]	PTRD[h]	ILD[i]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
1	100	100	100
0.45	*30.5*	*30.5*	*30.5*
1.5	100	100	100
0.68	*30.5*	*30.5*	*30.5*
2	100	100	100
0.9	*30.5*	*30.5*	*30.5*
3	100	100	100
1.4	*30.5*	*30.5*	*30.5*
5	100	100	100
2.3	*30.5*	*30.5*	*30.5*
7	100	100	100
3.2	*30.5*	*30.5*	*30.5*
10	100	100	100
4.5	*30.5*	*30.5*	*30.5*
15	100	100	100
6.8	*30.5*	*30.5*	*30.5*
20	100	100	100
9.1	*30.5*	*30.5*	*30.5*
30	107	100	100
13.6	*32.7*	*30.5*	*30.5*
50	118	100	100
22.7	*36.1*	*30.5*	*30.5*
70	127	100	100
31.8	*38.8*	*30.5*	*30.5*
100	138	100	100
45.4	*42.1*	*30.5*	*30.5*
150	152	100	100
68	*46.2*	*30.5*	*30.5*
200	162	100	100
90.7	*49.5*	*30.5*	*30.5*
300	179	107	100
136.1	*54.6*	*32.7*	*30.5*
500	202	121	100
226.8	*61.7*	*37*	*30.5*
700	219	132	100

Explosive Weight[d]	IBD[e, f, g]	PTRD[h]	ILD[i]
(lbs)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*
317.5	*66.8*	*40.1*	*30.5*
1000	238	143	100
453.6	*72.7*	*43.6*	*30.5*
1500	262	157	100
680.4	*79.8*	*47.9*	*30.5*
2000	279	168	101
907.2	*85.2*	*51.1*	*30.7*
3000	306	183	110
1361	*93.2*	*55.9*	*33.5*
5000	341	205	123
2268	*104*	*62.4*	*37.4*
7000	366	220	132
3175	*111.6*	*67*	*40.2*
10000	394	236	142
4536	*120*	*72*	*43.2*
15000	427	256	154
6804	*130.1*	*78.1*	*46.8*
20000	451	271	162
9072	*137.5*	*82.5*	*49.5*
30000	487	292	175
13608	*148.5*	*89.1*	*53.5*
50000	535	321	193
22680	*163*	*97.8*	*58.7*
70000	568	341	204
31751	*173.1*	*103.8*	*62.3*
100000	604	362	217
45359	*184.1*	*110.5*	*66.3*
150000	647	388	233
68039	*197.1*	*118.3*	*71*
200000	678	407	244
90718	*206.6*	*124*	*74.4*
300000	723	434	260
136077	*220.5*	*132.3*	*79.4*
500000	783	470	282
226795	*238.8*	*143.3*	*86*
>500,000	Footnote g	Footnote h	Footnote i
>226,795	*Footnote g*	*Footnote h*	*Footnote i*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	The QD criteria for HD 1.2.2 items are based on the hazards from primary fragments.
b	See Table 5-19. for a summary of IMD and minimum distances for ILD and PTRD.
c	See section 5.30.6.10 for storage and operations involving limited quantities of HD 1.2.2 without the need for siting as a PES.
d	Explosive Weight = Number of Items*NEWQD.
e	English EQN (IBD in ft, NEWQD in lbs; ln is natural logarithm) 20 lbs < Explosive Weight: IBD = 101.649 – [15.934*(ln(Number of items*NEWQD))] + [5.173* (ln(Number of items*NEWQD))^2], with a minimum of 100 ft *Metric EQN (IBD in m, NEWQD in kg; ln is natural logarithm)* *9.1 kg < Explosive Weight: IBD = 28.127 – [2.364*(ln(Number of items*NEWQD))] + [1.577* (ln(Number of items*NEWQD))^2], with a minimum of 30.5 m*
f	English EQN (IBD in ft, NEWQD in lbs; exp [x] is e^x) 100 ft < IBD < 1,240 ft: Number of items*NEWQD = exp [1.5401 + (-17.278 + 0.1933*IBD)$^{1/2}$] *Metric EQN (IBD in m, NEWQD in kg; exp [x] is e^x)* *30.5 m < IBD < 378 m: Number of items*NEWQD = exp [0.7495 + (-17.274 + 0.6341*IBD)$^{1/2}$]*
g	Use of equations given in Footnotes e and f to determine other IBD-weight combinations is allowed.
h	PTRD = 60% of IBD with a minimum distance equal to the IMD given in Table 5-19. for AGS (L). For other structures as either an ES or PES, see Table 5-19.
i	ILD = 36% of IBD with a minimum distance equal to the IMD given in Table 5-19. for the applicable PES-ES combination. For structures other than AGS (L) as either an ES or PES, see Table 5-19.

Table 5-19. Summary of Hazard Subdivisions 1.2.1, 1.2.2, and 1.2.3 Quantity-Distance[a,b,c]

To ES		From PES				
		ECM		AGS		
		S or R	F	(H)	(H/R)	(L)
ECM (7-Bar/3 Bar) (IMD)	S	0[d]	0[d]	0[d]	0[d]	0[d]
	R	0[d]	0[d]	0[d]	0[d]	0[d]
	FU	0[d]	0[d]	0[d]	0[d]	0[d]
	FB	0[d]	0[d]	0[d]	0[d]	0[d]
ECM (Undefined) (IMD)	S	0[d]	0[d]	0[d]	0[d]	0[d]
	R	0[d]	0[d]	0[d]	0[d]	0[d]
	FU	0[d]	200/300/100 ft	200/300/100 ft	200/300/100 ft	200/300/100 ft
		0[d]	61.0/91.4/30.5 m	61.0/91.4/30.5 m	61.0/91.4/30.5 m	61.0/91.4/30.5 m
	FB	0[d]	0[d]	0[d]	0[d]	0[d]
AGS (H/R) (IMD)	U or B	0[d]	0[d]	0[d]	0[d]	0[d]
AGS (H or L) (IMD)	U or B	0[d]	200/300/100 ft	200/300/100 ft	200/300/100 ft	200/300/100 ft
			61.0/91.4/30.5 m	61.0/91.4/30.5 m	61.0/91.4/30.5 m	61.0/91.4/30.5 m
ILD[e]		0[d]	Footnote f	Footnote f	Footnote f	Footnote f
PTR[e]		200/300/100 ft	Footnote g	Footnote g	Footnote g	Footnote g
		61.0/91.4/30.5 m				
IBD[e]		200/300/100 ft	Footnote h	Footnote h	Footnote h	Footnote h
		61.0/91.4/30.5 m				

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	For PES-ES combinations where three distances are given: the first refers to a PES containing HD 1.2.1 explosives with an MCE < 100 lbs [45.4 kg]; the second to a PES containing HD 1.2.1 explosives with an MCE > 100 lbs [45.4 kg]; and the third refers to a PES containing HD 1.2.2 AE. Where three IMD are given, the IMD from a PES containing only HD 1.2.3 explosives to an ES containing other than HD 1.2.3 is K11 [K_m4.36] based on the NEWQD of a single round of the largest (greatest NEWQD) HD 1.2.3 explosives in the PES.
b	For an ES containing only HD 1.2.3 items, the IMD from any PES to such an ES is 0 (Footnote d).
c	When the NEWQD and the MCE of the packaged HD 1.2.1 items fall within the ranges specified in the equation NEWQD < MCE < 450 lbs [204 kg], the HD 1.2.1 shall be treated as HD 1.1 and the criteria of section 5.32.5.2.1a as applicable, shall be used.
d	Practical considerations such as firefighting and security will dictate specific separation distances as
e	See Section 5.30.6.12. for HD 1.2.3.
f	ILD = 36% of IBD with a minimum distance equal to the IMD given in this table for the applicable PES-
g	PTRD = 60% of IBD with a minimum distance equal to the IMD given in this table for AGS (L).
h	For HD 1.2.1 items in any structure, truck, trailer or railcar, use the larger of the two applicable values given in Tables 5-16 and 5-17.; for HD 1.2.1 items in the open use Table 5-16.; for HD 1.2.2 items, use Table 5-18.

i	S = Side; R = Rear; F = Front; B = Barricaded; U = Unbarricaded; FU = Front Unbarricaded; FB = Front Barricaded; ECM = Earth-Covered Magazine (7-Bar, 3-Bar, or Undefined, which refers to the structural strength of the headwall and door(s)); AGM = Aboveground Magazine; AGS—Above ground site; HPM = High Performance Magazine; PES = Potential Explosion Site; ES – Exposed Site; AGS (H)—Aboveground site, Heavy Wall; Buildings with wall thickness > 12 inches of reinforced concrete; as an ES, door shall be barricaded if it faces a PES. AGS (H/R)—Above ground site, Heavy Wall and Roof; AGS (H) with roof thickness > 5.9 inches of reinforced concrete; as an ES, door shall be barricaded if it faces a PES; side/rear exposures may or may not be barricaded. AGS (L)—Aboveground site, Light; Light structure, open stack, truck, trailer, or railcar.

5.32.6.10 When storing mixed subdivisions of HD 1.2 explosives (HD 1.2.1 and HD 1.2.2), the following rule shall apply: Consider each subdivision separately and apply the greater of the two distances. The general mixing rules for HD 1.2 explosives are given in Table 5-20.

5.32.6.11 For reasons of operational necessity In Accorgance With (IAW) NASA Center defined procedures, limited quantities of HD 1.2.2 items may be stored in facilities such as hangars, arms rooms, security alert force rooms, manufacturing or operating buildings may be stored without the need for siting as a PES. Operations involving limited quantities of HD 1.2.2 items are also permitted without the need for siting as a PES IAW NASA Center defined procedures, for reasons of operational necessity. NASA Center procedures should address items such as NEWQD limits, documentation requirements, approval process, and LPS requirements.

5.32.6.12 Unit Risk HD 1.2 is a special storage subdivision (HD 1.2.3) for explosives that satisfy either of the following sets of criteria:

a. Explosives that satisfy the criteria for HD 1.6 with the exception of containing a non-EIDS device, or

Table 5-20. Hazard Subdivisions 1.2.1, 1.2.2, and 1.2.3 Mixing Rule

Hazard Sub-Division Involved	Distances to be Applied
1.2.1	Apply HD 1.2.1 distances[a]
1.2.2	Apply HD 1.2.2 distances[b]
1.2.3	Apply HD 1.2.3 distances[c]
1.2.1 + 1.2.2	Apply greater of two distances
1.2.1 + 1.2.3	Apply greater of two distances
1.2.2 + 1.2.3	Apply greater of two distances

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	HD 1.2.1 distances given in Tables 5-16, 5-17, and 5-19.
b	HD 1.2.2 distances given in Tables 5-18 and 5-19.
c	HD 1.2.3 distances given in Table 5-21.

b. Explosives that do not exhibit any sympathetic detonation response in the stack test (UN Test 6(b)) or any reaction more severe than burning in the external fire test (UN Test 6(c)), bullet impact test (UN Test 7(j)), and the slow cook-off test (UN Test 7(h)).

5.32.6.13 The IBD for Unit Risk HD 1.2 (HD 1.2.3) shall be determined using Table 5-21 (HD 1.3 Quantity-Distances) for the NEWQD of the HD 1.2.3 item multiplied by the number of items present, but with a minimum IBD determined as follows:

5.32.6.14 If the items are in a structure that can interrupt primary fragments and can contribute debris, the minimum IBD shall be the hazardous debris distance given in Table 5-17 for an MCE equal to the NEWQD of a single item. If the items are in the open or in a light structure that will not interrupt primary fragments, the minimum IBD shall be the hazardous primary fragment distance based on the HD 1.1 hazardous fragment area number density criteria applied to a single HD 1.2.3 item. PTRD for HD 1.2.3 shall be equal to 60% of IBD. ILD shall be computed as 36% of IBD, with a minimum distance equal to the IMD.

5.32.6.15 IMD shall be as given in Table 5-19. For any specific quantity or distance determination, as an alternative to the preceding HD 1.2.3 QD criteria, when an increase in the allowable quantity or a reduction in the required distance will result, items hazard classified as HD 1.2.3 may be treated as follows: If the single-item NEWQD is greater than 1.6 pounds, consider the items as HD 1.2.1 (use the total NEWQD present, with an MCE equal to the NEWQD of one item). If the single-item NEWQD is equal to or less than 1.6 pounds, consider the items as HD 1.2.2, based on the total NEWQD present.

5.32.6.16 For storage of mixed Unit Risk HD 1.2 (HD 1.2.3) explosives, the NEWQD for the HD 1.2.3 items shall be multiplied by the corresponding number of HD 1.2.3 items and use Table 5-20 with a hazardous fragment distance based on the largest hazardous fragment distance for the HD 1.2.3 explosives in storage.

5.32.6.17 When HD 1.2.3 explosives are located with any other Hazard Division 1.2 subdivision, the distances given in Table 5-20 shall be used.

5.32.6.18 When HD 1.2.3 explosives are located with any other HD explosives, the HD 1.2.3 explosives shall be considered HD 1.2 (HD 1.2.1 or HD 1.2.2, according to NEWQD) for QD purposes.

5.32.6.19 The mixing rules provided in Sections 5.29.7 and 5.29.8 above shall then be applied to the combination of the hazard divisions.

5.32.7 Hazard Division 1.3.

5.32.7.1 Hazard Division 1.3 includes items that burn vigorously with little or no possibility of extinguishment in storage situations. Explosions normally will be confined to pressure ruptures of containers and will not produce propagating shock waves or damaging blast overpressure beyond the magazine distance specified in Table 5-21. A severe hazard of spread of fire may result from tossing about of burning container materials, propellant, or other flaming debris. In a HD 1.3 event, some HE or HE components may become propulsive and travel well beyond IBD.

Table 5-21. Hazard Division 1.3 Quantity-Distances[a, b]

NEWQD	IBD & PTRD[c]	Aboveground IMD & ILD[d]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
≤ 1000[e]	75	50
≤ 453.59[e]	*22.9*	*15.2*
1,500	82	56
680.4	*25*	*17*
2,000	89	61
907.2	*27.2*	*18.5*
3,000	101	68
1,360.80	*30.7*	*20.8*
5,000	117	80
2,268.00	*35.8*	*24.3*
7,000	130	88
3,175.10	*39.6*	*26.9*
10,000	145	98
4,535.90	*44.2*	*30*
15,000	164	112
6,803.90	*50.1*	*34*
20,000	180	122
9,071.80	*54.8*	*37.2*
30,000	204	138
13,607.70	*62.3*	*42.2*
50,000	240	163
22,679.50	*73.2*	*49.5*
70,000	268	181
31,751.30	*81.6*	*55.1*
100,000	300	204
45,359.00	*91.4*	*62*
150,000	346	234
68,038.50	*105.3*	*71.4*
200,000	385	260
90,718.00	*117.4*	*79.3*
300,000	454	303
136,077.00	*138.4*	*92.5*
500,000	569	372
226,795.00	*173.6*	*113.4*
700,000	668	428
317,513.00	*203.8*	*130.5*

NEWQD	IBD & PTRD[c]	Aboveground IMD & ILD[d]
(lbs)	(ft)	(ft)
[kg]	*[m]*	*[m]*
1,000,000	800	500
453,590.00	*244*	*152.3*
1,500,000	936	577
680,385.00	*285.3*	*175.8*
2,000,000	1,008	630
907,180.00	*307.2*	*192*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	For reasons of operational necessity, limited quantities of items in this hazard division, such as document destroyers, signaling devices, riot control munitions, and similar equipment, may be stored without the need for siting as a PES in accordance with fire protection regulations, in facilities such as hangars, arms rooms, security alert force rooms, and manufacturing or operating buildings. Operations involving limited quantities of HD 1.3 items are also permitted without the need for siting as a PES IAW NASA Center defined procedures, for reasons of operational necessity. NASA Center procedures should address items such as NEWQD limits, documentation requirements, approval process, and LPS requirements.
b	Existing ECM, regardless of orientation, that meet the construction and barricading requirements, for HD 1.1 and are sited for a minimum of 100 lbs [45.4 kg] NEWQD of HD 1.1 (using the ECM-to-ECM QD criteria in Table 5-12) may be used to their physical storage capacity for HD 1.3, provided all other QD relationships are sited per this table for the HD 1.3 NEWQD.
c	English EQNs (NEWQD in lbs, d in ft; exp [x] is e^x, ln is natural logarithm) NEWQD $\leq$ 1,000 lbs: $d_{IBD,PTRD}$ = 75 ft 1,000 lbs < NEWQD $\leq$ 96,000 lbs: $d_{IBD,PTRD} = \exp [2.47 + 0.2368*(\ln(NEWQD)) + 0.00384*(\ln(NEWQD))^2]$, with a minimum distance of 75 ft. 96,000 lbs < NEWQD $\leq$ 1,000,000 lbs: $d_{IBD,PTRD} = \exp [7.2297 - 0.5984*(\ln(NEWQD)) + 0.04046*(\ln(NEWQD))^2]$ 1,000,000 lbs < NEWQD: $d_{IBD,PTRD} = 8*NEWQD^{1/3}$ 75 ft $\leq d_{IBD,PTRD} \leq$ 296 ft: $NEWQD = \exp [-30.833 + (307.465 + 260.417*(\ln(d_{IBD,PTRD})))^{1/2}]$, with a minimum NEWQD of 1000 lbs. 296 ft < $d_{IBD,PTRD} \leq$ 800 ft: $NEWQD = \exp [7.395 + (-124.002 + 24.716*(\ln(d_{IBD,PTRD})))^{1/2}]$ 800 ft < $d_{IBD,PTRD}$; $NEWQD = (d_{IBD,PTRD})^3 / 512$

c	*Metric EQNs (NEWQD in kg, d in m; exp [x] is e^x, ln is natural logarithm)*
	NEWQD $\leq$ 453.6 kg: $d_{IBD,PTRD}$ *= 22.9 m*
	453.6 kg < NEWQD $\leq$ 43,544.6 kg: $d_{IBD,PTRD} = \exp [1.4715 + 0.2429*(\ln(NEWQD)) + 0.00384*(\ln(NEWQD))^2]$*, with a minimum distance of 22.9 m*
	43,544.6 kg < NEWQD $\leq$ 453,590 kg: $d_{IBD,PTRD} = \exp [5.5938 - 0.5344*(\ln(NEWQD)) + 0.04046*(\ln(NEWQD))^2]$
	453,590 kg < NEWQD: $d_{IBD,PTRD} = 3.17*NEWQD^{1/3}$
	22.9 m $\leq d_{IBD,PTRD} \leq$ 90.2 m: $NEWQD = \exp [-31.628 + (617.102 + 260.417*(\ln(d_{IBD,PTRD})))^{1/2}]$*, with a minimum NEWQD of 453.6 kg*
	90.2 m < $d_{IBD,PTRD} \leq$ 243.8 m: $NEWQD = \exp [6.604 + (-94.642 + 24.716*(\ln(dIBD,PTRD)))^{1/2}$
	243.8 m < $d_{IBD,PTRD}$: $NEWQD = (d_{IBD,PTRD})^3 / 131.964$

d	English EQNs (NEWQD in lbs, d in ft; exp [x] is e^x, ln is natural logarithm) NEWQD $\leq$ 1,000 lbs: $d_{IMD,ILD}$ = 50 ft 1,000 lbs < NEWQD $\leq$ 84,000 lbs: $d_{IMD,ILD} = \exp [2.0325 + 0.2488*(\ln(NEWQD)) + 0.00313*(\ln(NEWQD))^2]$, with a minimum distance of 50 ft 84,000 lbs < NEWQD $\leq$ 1,000,000 lbs: $d_{IMD,ILD} = \exp [4.338 - 0.1695*(\ln(NEWQD)) + 0.0221*(\ln(NEWQD))^2]$ 1,000,000 lbs < NEWQD: $d_{IMD,ILD} = 5*NEWQD^{1/3}$ 50 ft $\leq d_{IMD,ILD} \leq$ 192 ft: $NEWQD = \exp [-39.744 + (930.257 + 319.49*(\ln(d_{IMD,ILD})))^{1/2}]$, with a minimum NEWQD of 1,000 lbs 192 ft < $d_{IMD,ILD} \leq$ 500 ft: $NEWQD = \exp [3.834 + (-181.58 + 45.249*(\ln(dIMD,ILD)))^{1/2}]$ 500 ft < $d_{IMD,ILD}$: $NEWQD = (d_{IMD,ILD})^3/125$ *Metric EQNs (NEWQD in kg, d in m; exp [x] is e^x, ln is natural logarithm)* *NEWQD $\leq$ 453.6 kg:* $d_{IMD,ILD}$ = 15.2 m *453.6 kg < NEWQD $\leq$ 38,101.6 kg:* $d_{IMD,ILD} = exp [1.0431 + 0.2537*(\ln(NEWQD)) + 0.00313*(\ln(NEWQD))^2]$, with a minimum distance of 15.2 m *38,101.6 kg < NEWQD $\leq$ 453,590 kg:* $d_{IMD,ILD} = exp [3.0297 - 0.1346*(\ln(NEWQD)) + 0.0221*(\ln(NEWQD))^2]$ *453,590 kg < NEWQD:* $d_{IMD,ILD} = 1.98*NEWQD^{1/3}$ *15.2 m $\leq d_{IMD,ILD} \leq$ 58.4 m:* $NEWQD = exp [-40.527 + (1309.19 + 319.49*(\ln(d_{IMD,ILD})))^{1/2}]$, with a minimum NEWQD of 453.6 kg
e	*For quantities less than 1,000 lbs [453.59 kg], the required distance are those specified for 1,000 lbs [453.59 kg]. The use of lesser distances may be approved when supported by testdata or analysis.*

5.32.8 For solid rocket motor static test stands, use TNT equivalents, $D = 24W^{1/3}$ for workers, and IBD from Table 5-10 for all others, when uncertainties are identified during pre-test reviews. When no uncertainties are identified, use distances for 1.3 quantities per the table.

5.32.9 Hazard Division 1.4.

5.32.9.1 HD 1.4 explosives present a fire hazard with minimal blast, fragmentation, or toxic hazards. Facilities for storage and handling of these items shall be located in accordance with Table 5-22.

5.32.9.2 Items hazard classified as HD 1.4S may be stored (including associated handling) without regard to the QD criteria in Table 5-22.

Table 5-22. Hazard Division 1.4 Quantity Distances[a]

NEWQD[b]	IBD/PTRD[c]	ILD[d, e]	AGS (L)	AGS(H) & (H/R) IMD[e,]	EC M
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
$\leq$ 3000[g]	75	50	50	0 to and from	0 to and from the sides and rear; see Footnote j for the front
$\leq$ 1,360.8[g]	*22.9*	*15.3*	*15.3*		
>3000[h]	100	100/50[i]	100/50[i]		
>1,360.8[h]	*30.5*	*30.5/15.3[i]*	*30.5/15.3[i]*		

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	HD 1.4 explosives may be stored in a general supplies warehouse area rather than in an explosives storage area, provided they are enclosed in an appropriate magazine or a Class 5 or 6 security file cabinet meeting the requirements of GSA Specification AA-F-358. When storing in a general supplies warehouse any weatherproof warehouse structure may serve as an HD 1.4 magazine. Such a structure will be separated from all other warehouses per the AGS (L) IMD column of this table.
b	See section 5.29.8 for the applicability of HD 1.4 QD criteria and the determination of NEWQD when HD 1.4 and other HD explosives are located in the same site.
c	IBD and PTRD are 50 ft [15.3 m] from the sides and rear of an ECM. IBD and PTRD are 50 ft [15.3 m] from an AGS (H), an AGS (H/R), and an ECM front that meets the definition of AGS (H); doors and other openings shall be barricaded IAW DoD 6055.09, section V2.E5.4, or the IBD or PTRD column of this table applied from these doors and openings.
d	ILD is 0 ft from the sides and rear of an ECM. ILD is 0 ft from an AGS (H), an AGS (H/R), and an ECM front that meets the definition of AGS (H); doors and other openings shall be barricaded IAW DoD 6055.09, section V2.E5.4, or the ILD column of this table applied from these doors and openings.
e	Magazines storing only HD 1.4 explosives may be located at these IMD or ILD from all other magazines or operating buildings regardless of the HD or NEWQD authorized in those adjacent structures. Because the HD 1.4 explosives may be destroyed as the result of a mishap involving the assets in those adjacent structures, application of this provision shall be accepted by the NASA Center ESO on a case-by-case basis with consideration given to the value of HD 1.4 assets at risk.
f	Doors and other openings shall be barricaded IAW DoD 6055.09, section V2.E5.4, or the AGS (L) IMD column of this table applied to and from these doors and openings.
g	For reasons of operational necessity, and IAW NASA Center procedures, limited quantities of HD 1.4 explosives, (e.g., small arms ammunition and riot control munitions) may be stored, in accordance with fire protection regulations, within facilities (e.g., hangars, arms rooms, security alert force rooms, and manufacturing or operating buildings) without the need for siting or licensing as a PES IAW NASA Center defined procedures, for reasons of operational necessity. Alternatively, operationally necessary HD 1.4 explosives may be stored in small magazines external to those facilities without regard to QD. NASA Center procedures should address items such as NEWQD limits, documentation requirements, approval process, and LPS requirements.
h	There is no upper limit on the NEWQD specifically required for safety reasons.
i	Use the smaller distance when the ES is of non-combustible construction.
j	Apply the appropriate AGS column of this table based on whether the ECM front meets the definition of AGS (L) or AGS (H).

5.32.10 Hazard Division 1.6.

5.32.10.1 QD separations for Hazard Division 1.6 explosives shall be based on the storage location and configuration.

5.32.10.2 This information is detailed in Table 5-23 and accompanying footnotes. A maximum of 500,000 NEW shall be permitted at any one location. Any special storage configuration and siting approved for Hazard Division 1.1 explosives may be used for storage of like explosives weights of Hazard Division 1.6 explosives.

Table 5-23. Quantity-Distance Criteria for Hazard Division 1.6 Explosives

NEWQD	Aboveground		ECM		
	IBD or PTRD[a, b, c]	IMD or ILD[a, c, d]	IBD or PTRD	ILD	IMD
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
≤100[e]	37	23	Footnote c	Footnote c	Footnote c
<45.4[e]	*11.3*	*7*			
150	43	27			
68	*12.9*	*8.1*			
200	47	29			
90.7	*14.3*	*8.9*			
300	54	33			
136.1	*16.3*	*10.2*			
500	63	40			
226.8	*19.4*	*12.1*			
700	71	44			
317.5	*21.7*	*13.5*			
1000	80	50			
453.6	*24.4*	*15.2*			
1500	92	57			
680.4	*27.9*	*17.4*			
2000	101	63			
907.2	*30.7*	*19.2*			
3000	115	72			
1360.8	*35.2*	*22*			
5000	137	85			
2268	*41.7*	*26.1*			
7000	153	96			
3175.1	*46.6*	*29.2*			
10000	172	108			
4535.9	*52.5*	*32.8*			
15000	197	123			
6803.9	*60.1*	*37.6*			
20000	217	136			
9071.8	*66.2*	*41.4*			
30000	249	155			
13607.7	*75.8*	*47.4*			
50000	295	184			
22679.5	*89.8*	*56.1*			
70000	330	206			
31751.3	*100.5*	*62.8*			
100000	371	232			
45359	*113.2*	*70.7*			

NEWQD	Aboveground		ECM		
	IBD or PTRD[a, b, c]	IMD or ILD[a, c, d]	IBD or PTRD	ILD	IMD
(lbs)	(ft)	(ft)	(ft)	(ft)	(ft)
[kg]	*[m]*	*[m]*	*[m]*	*[m]*	*[m]*
150000	425	266			
68038.5	*129.6*	*81*			
200000	468	292			
90718	*142.6*	*89.1*			
300000	536	335			
136077	*163.2*	*102*			
500000	635	397			
226795	*193.5*	*121*			

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Applicable minimum distances:
	English EQNs (D in ft, NEWQD in lbs) For IBD or PTRD, based on the NEWQD for the largest single round of explosives: $D_{IBD,PTRD} = 40*W^{1/3}$ For IMD or ILD, based on the NEWQD for the largest single round of explosives: $D_{IMD, ILD} = 18*W^{1/3}$
	Metric EQNs (D in m, NEWQD in kg) *For IBD or PTR, based on the NEWQD for the largest single round of explosives:* $D_{IBD,PTRD} = 15.87*Q^{1/3}$ *For IMD or ILD, based on the NEWQD for the largest single round of explosives:* $D_{IMD, ILD} = 7.14*Q^{1/3}$
b	English EQNs (D in ft, NEWQD in lbs) $D_{IBD,PTRD} = 8*W^{1/3}$ $NEWQD = (D_{IBD,PTRD})^3/512$
	Metric EQNs (D in m, NEWQD in kg) $D_{IBD,PTRD} = 3.17*Q^{1/3}$ $NEWQD = (D_{IBD,PTRD})^3 /31.86$
c	For HD 1.6 explosives packed in non-flammable pallets or packing and stored in an ECM, provided it is acceptable to the NASA Center ESO on a site-specific basis, these QD apply unless a lesser distance is permitted by this table for aboveground sites (These lesser distances can be applied to ECM storage): $D_{IBD,PTRD}$ = 100 ft [30.5 m]; D_{ILD} = 50 ft [15.2 m]; D_{IMD} = no specific requirement.
d	English EQNs (D in ft, NEWQD in lbs) $D_{IMD, ILD} = 5*W^{1/3}$ $NEWQD = (D_{IMD, ILD})^3/125$
	Metric EQNs (D in m, NEWQD in kg) $D_{IMD, ILD} = 1.98*Q^{1/3}$ $NEWQD = (D_{IMD, ILD})^3/7.76$

e	For quantities less than 100 lbs [45.4 kg], the required distances are those specified for 100 lbs [45.4 kg]. The use of lesser distances may be approved when supported by test data or analyses.

5.32.11 Classification Yards.

5.32.11.1 For protection of the classification yard from external explosions, separation distances shall be at least the applicable magazine distance.

5.32.11.2 Specific QD separation is not required from the classification yard to targets other than explosives locations when the classification yard is used exclusively for:

a. Interchanging of trucks, trailers, or railcars between the common carrier and the receiving, dispatching, classifying, and switching of cars

b. NASA activity

c. Conducting of external inspection of motor vehicles or railcars, or opening of free rolling doors of railcars for the purpose of removing documents and making a visual inspection of the cargo.

5.32.11.3 If the yard is used at any time for any purpose other than NASA activity such as placing or removal of dunnage or explosives items into or from railcars, QD tables apply.

5.32.12 Interchange Yards. Truck, trailer, or railcar interchange yards are not subject to QD regulations when they are used exclusively:

a. For the interchange of vehicles or railcars containing explosives between the commercial carrier and NASA activities

b. To conduct external inspection of the trucks, trailers, or railcars containing explosives.

c. To conduct visual inspection of the external condition of the cargo in vehicles (such as trucks, trailers, and railcars) that passed the external inspection. If the yards are used at any time for any purpose other than above, applicable QD tables apply.

5.32.13 Loading Docks. Detached loading docks which normally service multiple facilities are sited on the basis of use. When servicing magazines, they shall be separated from the magazines by IMDs.

5.32.14 When servicing operating buildings, they shall be separated from the operating buildings by ILDs.

5.32.15 Railcar and Truck Holding Yards.

5.32.15.1 Generally, railcar holding yards shall be laid out on a unit railcar group basis with each group separated by the applicable aboveground magazine distance.

5.32.15.2 If the railcar holding yard is formed by two parallel ladder tracks connected by diagonal spurs, the parallel tracks and the diagonal spurs shall be separated by applicable aboveground magazine distance for the unit group quantities of explosives.

5.32.15.3 If the railcar holding yard is a "Christmas tree" arrangement, consisting of a ladder track with diagonal dead end spurs projecting from each side at alternate intervals, the spurs shall be separated by the applicable aboveground magazine distance for the net weight of explosives in the railcars on the spurs.

5.32.15.4 Generally, truck holding yards shall be laid out on a unit truck group basis with each group separated by the applicable aboveground magazine distances.

5.32.15.5 Both railcar and truck holding yards shall be separated from other facilities by the applicable IBD, PTRD, ILD or IMD QD criteria.

5.32.15.6 In addition to the temporary parking of railcars, trucks, or trailers containing explosives, holding yards may also be used to interchange trucks, trailers, or railcars between the commercial carrier and the NASA activity and to conduct visual inspections.

5.32.16 Railcar and Truck Inspection Stations.

5.32.16.1 Vehicle and cargo inspections shall be performed for all incoming shipments of Class 1 explosives, excluding HD 1.4, upon entering the Center/Facility. Specific QD separations are not required for inspection stations; however, they should be as remote as practicable from hazardous or populated areas. Activities that may be performed at the inspection station after railcars or motor vehicles containing explosives are received from the delivering carrier and before further routing within the Center are:

a. External visual inspection of the railcars or motor vehicles.

b. Visual inspection of the external condition of the cargo packaging in vehicles (such as trucks, trailers, and railcars) that have passed the external inspection.

c. Interchange of trucks, trailers, or railcars between the common carrier and the NASA activity.

5.32.16.2 If any activities other than the above are conducted at the inspection station, QD applies.

5.32.16.3 Any railcars or trucks suspected of being in a hazardous condition shall be isolated, consistent with applicable QD separation for the hazard class and explosives quantity involved, before any other action.

5.32.17 Explosives Transportation Mode Change Locations. Movement and transfer of NASA-titled explosives shall be in compliance with national, international, and host country-specific transportation regulations. QD criteria apply to all transfer operations involving NASA-titled explosives except for:

a. Roll-on/roll-off operations (not involving lifting); and

b. Off-Center Military Van (MILVAN)/International Organization For Standardization (ISO) container inter/intramodal transfers (involving highway and rail modes only) where containers are not stored or other operations are performed.

5.32.18 Storage Tanks for Hazardous Materials.

5.32.18.1 Large permanent storage facilities are of primary concern when applying QD criteria to storage tanks. For installation of smaller tanks, it may be desirable to weigh the cost of distance and/or protective construction against the strategic value of the stored material, the ease of replacement in the event of an accident, and the potential environmental impact. Reduced distances may be approved if these losses are accepted by the appropriate NASA Center, if the tanks are sited, and if spill containment is provided so other exposures are not endangered.

5.32.18.2 Small quantities of POL and other hazardous materials used for operational purposes require no specific separation distance for explosives safety; however, operating procedures shall be implemented to limit adverse environmental impacts in the event of an accidental explosion.

5.32.18.3 Unprotected, aboveground storage tanks shall be separated from other PESs at IBD per Table 5-10, as a minimum, and shall be diked.

5.32.18.4 Unprotected service tanks, which provide sole support to aboveground explosives storage and operating complexes and are supplied by a pipe system designed to resist potential blast and fragments, may be sited at incremented IMD distances with a minimum distance of 400 ft., provided:

a. A dike system, meeting the requirements in NFPA 30, is provided; and,

b. The NASA Center accepts the possible loss of the tanks and any collateral damage that a fire might cause as a result of the tanks being punctured by fragments.

5.32.18.5 A service tank supporting a single PES shall be separated, at a minimum, from that PES by the greater of the appropriate NFPA fire protection distance or the required distance between the PESs.

5.32.18.6 Distances less than those for unprotected tanks may be used when an aboveground storage tank is provided sufficient protection from blast and fragment hazards to prevent rupture or collapse.

5.32.18.7 Buried tanks and buried pipelines shall be separated from aboveground buildings or stacks containing explosives of Hazard Divisions 1.2, 1.3, and 1.4 by a minimum distance of 80 ft., and from explosives in Hazard Division 1.1 by a minimum of the K3 distance of 80 ft.

5.32.18.8 It is not practical to specify QD criteria that cover all configurations involving tank storage facilities. Each case shall be assessed on a site specific basis to take account of crater, blast, ground shock, debris hazards, and potential adverse environmental impacts.

5.32.19 Airfields and Heliports.

5.32.19.1 This section applies to explosives, which are under the control and custody of NASA personnel, at or near airfields and heliports. Its provisions do not apply to explosives items installed on aircraft or contained in survival and rescue kits such as flares, signals, egress system components, squibs, and detonators for jettisoning external stores, engine starter cartridges, fire extinguisher cartridges, destructors in electronic equipment,

explosives components of emergency equipment, and other such items or materials necessary for safe flight operations.

5.32.19.2 Aircraft loaded with the explosives, given in Sections below, are exempt from QD requirements when evaluated as a PES:

a. HD 1.2 - gun ammunition, 30 mm or less.

b. HD 1.3 - captive missiles or aircraft defensive flare/chaff.

c. HD 1.4 - explosives.

5.32.19.3 These aircraft shall be parked in designated aircraft parking areas that meet airfield criteria.

5.32.19.4 Uploading and downloading of explosives shall be conducted in explosives sited aircraft parking areas with the exception of explosives listed in Section 5.32.19.2.a These items can be uploaded and downloaded at the designated aircraft parking areas provided that the quantity of explosives involved in the operation is limited to a single aircraft load.

5.32.19.5 These QDs are applied in conjunction with airfield clearance criteria as prescribed by NASA Centers and Federal Aviation Regulations as follows:

a. For airfields and heliports used exclusively by NASA, explosives loaded aircraft parking areas, explosives cargo areas, alert hangars, and shelters may be located within the airfield clearance zone insofar as these QD standards are concerned, except in the explosives prohibited areas as described in section 5.32.19.6.

b. For airfields and heliports not used exclusively by NASA, explosives loaded-aircraft parking areas, explosives cargo areas, alert hangars, and shelters shall be located as prescribed in Table 5-24 and Table 5-25.

Table 5-24. Hazard Division 1.1 - Quantity-Distance for Explosives Loaded Aircraft Parking Areas

NEWQD	Distance for Specific Targets Indicated in Table 5-25[a,b,c]	NEWQD	Distance for Specific Targets Indicated in Table 5-25[a,b,c]
(lbs) *[kg]*	(ft) [m]	(lbs) [kg]	(ft) [m]
50 *22.7*	111 33.7	7,000 3,175.1	574 174.9
70 *31.8*	124 37.7	10,000 4,535.9	646 197.0
100 *45.4*	139 42.4	15,000 6,803.9	740 225.5
150 *68.0*	159 48.6	20,000 9,071.8	814 248.2
200 *90.7*	175 53.5	30,000 13,608	932 284.1
300	201	50,000	1,105

NEWQD	Distance for Specific Targets Indicated in Table 5-25[a,b,c]	NEWQD	Distance for Specific Targets Indicated in Table 5-25[a,b,c]
(lbs)	(ft)	(lbs)	(ft)
[kg]	[m]	[kg]	[m]
136.1	61.2	22,680	336.9
500	238	70,000	1,236
226.8	72.6	31,751	376.9
700	266	100,000	1,392
317.5	81.2	45,359	424.4
1,000	300	150,000	1,594
453.6	91.4	68,039	485.8
1,500	343	200,000	1,754
680.4	104.7	90,718	534.7
2,000	378	300,000	2,008
907.2	115.2	136,077	612.1
3,000	433	500,000	2,381
1,360.8	131.9	226,795	725.8
5,000	513		
2,268.0	156.4		

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	English equations (EQNs) (D in ft, NEWQD in lbs) $D = 30*W^{1/3}$ with a minimum distance of 111 ft $NEWQD = D^3/27{,}000$ with a minimum NEWQD of 50 lbs *Metric EQNs (D in m, NEWQD in kg)* *$D = 11.9*Q^{1/3}$ with a minimum distance of 33.8 m* *$NEWQD = D^3/1{,}685.2$ with a minimum NEWQD of 22.7 kg*
b	Minimum fragment distance requirements for HD 1.1 do not apply to targets for which this table is used.
c	To protect against low-angle, high-speed fragments, barricades should be provided; however, these distances shall not be reduced.

Table 5-25. Application of Explosives Safety Distances (Airfields and Heliports)

To:	From:				
	Explosives Loaded Aircraft Parking Area	Explosives Cargo Area	Explosives Storage Facility	Explosives Operating Facility	Ready Explosives Storage Facility
Explosives Loaded Aircraft Parking Area	a	a	b	b	a
Explosives Cargo Area	a	a	a	a	a

To:	From:				
	Explosives Loaded Aircraft Parking Area	Explosives Cargo Area	Explosives Storage Facility	Explosives Operating Facility	Ready Explosives Storage Facility
Explosives Storage Facility	a	a	a	a	a
Explosives Operating Facility	c	c	c	c	c
Ready Explosives Storage Facility	a	a	a	a	a
Inhabited Building	d	d	d	d	d
PTR and Taxiway (joint NASA - Non NASA use)	e	e	e	e	e
Runway (joint NASA - Non NASA use)	d	d	d	d	d
Runway/Taxiway (NASA use only)	None	None	f	e	None
Aircraft Parking Area	g	g	h	h	g
Aircraft Passenger Loading/Unloading Area	i	i	i	i	i
Recreation Area	j	k	k	k	j

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	For Hazard Division 1.1 explosives, use appropriate IMD. For Hazard Division 1.2 (1.2.1, 1.2.2 and/or 1.2.3), apply footnote g, below. Protects against simultaneous detonation of explosives on adjacent aircraft, but does not prevent serious damage to aircraft and possible propagation of detonation due to fragments, debris, or fire.
b	Use Table 5-24 distances for mass detonating items and applicable PRTD for non-mass
c	Use applicable ILD.
d	Use applicable IBD.
e	Use applicable PTRD.
f	For HD 1.1, use unbarricaded ILD per Table 5-11 from side or rear of ECMs to taxiways; for HD 1.2, HD 1.3 or HD 1.4, no separation is required from side or rear of ECMs to taxiways. Use PTRD from front of ECMs or any other storage locations to taxiways. Use PTRD from all storage locations to runways.
g	Within these areas of airfields and heliports exclusively used by NASA, the separation of aircraft parking areas from explosives loaded aircraft parking areas and their ready explosives storage facilities and explosives cargo areas are considered to be a NASA Center function approved by the ESO. At joint NASA/non NASA use airfields and heliports, the explosives loaded aircraft parking areas and its ready explosives storage facilities and explosives cargo area shall be separated from non NASA aircraft as specified in footnote h.
h	Use Table 5-24 distances for NASA aircraft parking areas, and appropriate IBD for non NASA aircraft parking areas.

i	Use applicable PTRD for locations in the open where passengers enplane and deplane. Use applicable IBD if a structure is included where passengers assemble, such as a passenger terminal building.
j	No distance required to recreational areas that are used exclusively for alert personnel manning the explosives loaded aircraft. Other recreational areas where people are in the open shall be at appropriate PTRD. When structures, including bleacher stands, are a part of such area, appropriate IBD shall be used.
k	Recreational areas, where people are in the open, shall be at applicable PTRDs. When structures, including bleacher stands are part of such areas, applicable IBDs shall be used.

5.32.19.6 Measurement of Separation Distances. In applying Table 5-24 and 5-25, distances shall be measured as follows:

a. Loaded Aircraft to Loaded Aircraft. Measure the shortest distance between explosives on one aircraft to explosives on the adjacent aircraft.

b. Explosives Location to Taxiways and Runways. Measure from the nearest point of the explosives and explosives location to the nearest point of the taxiway and to the centerline of the runway.

5.32.19.7 Explosives Prohibited Areas. All explosives shall be prohibited in any area under approach and departure zones of all fixed and rotary wing aircraft landing facilities (NASA, other federal, joint use, and civil). The approach and departure zone surface or areas for aircraft are those so designated and described in detail for the various types of facilities in NASA airfield and airspace criteria directives. In general, the approach and departure zone begins near the end of a runway or landing area and extends outward to a given distance along, and symmetrically on each side of, the extended runway centerline or the aircraft approach axis of a heliport. Such zones flare uniformly from the landing area outward to a prescribed limit.

5.32.20 Utilities Installations. Permanent NASA-controlled underground utilities installations (excluding building service lines) shall be separated from explosives locations containing Class 1.1 materials according to Table 5-26.

Table 5-26. Quantity-Distance Separation for Protection of Underground Service Installations

Quantity of explosives (maximum)	**Distance**
(lbs)	(ft)
[kg]	[m]
100	80
45.4	26
200	80
90.7	26
500	80
226.8	26
1,000	80
453.4	26

Quantity of explosives (maximum)	Distance
(lbs)	(ft)
[kg]	[m]
2,000	80
907.2	26
5,000	80
2268.0	26
10,000	80
4535.9	26
20,000	85
9071.8	28
50,000	110
22,679.6	36
100,000	140
45,359.2	46
250,000	190
113,398.1	62

(Reference: DOE-STD-1212-2012, June 2012)

NOTES: If the potential donor building is designed to contain the effects of an explosion, the formula $D = 3.0\ W^{1/3}$ can be used to determine separation distances for less than 20,000 lbs (9071.8 kg).

5.32.20.1 Utilities installations (aboveground and underground) that are privately owned or operated shall be separated from explosives locations by at least PTR distances.

5.32.20.2 If these installations include structures, they shall be separated from explosives facilities by IBD.

5.32.21 Energetic Liquids.

5.32.21.1 Scope and Application. This section applies to the storage of energetic liquids (Table 5-27) in all types of containers, including rocket and missiles tankage. Laboratory quantities shall be stored and handled as prescribed in Section 5.11.

Note: The required QD are only based on the energetic liquids' energetic reaction (blast overpressure and container fragmentation). These QD requirements do not consider the toxicity or potential down-wind hazard. Therefore, QD may not be the only factor that needs to be considered when selecting a location for storage and operations of energetic liquids.

5.32.21.2 Concept. These QD standards were developed on the premise that the applicable NASA Center will ensure that the materials of construction are compatible with the energetic liquids, facilities are of appropriate design, fire protection and drainage control techniques are employed, and other specialized controls (such as nitrogen padding, blanketing, and tank cooling) are used when required.

a. When additional hazards associated with explosives are involved, the safety distances prescribed in other sections shall be applied, as appropriate.

b. These standards are based upon the estimated credible damage resulting from an incident, without considering probabilities or frequency of occurrence.

Table 5-27. Hazard Classifications and Minimum QD for Energetic Liquids

Energetic Liquid	OSHA/NFPA Fuel[a] or Oxidizer[b] Class	DoD Storage Hazard Class	Minimum QD[c]
H_2O_2 > 60%	3 or 4[d]	5.1 (LA)	800[e] ft or Table 5-31 243.8[e] m or Table 5-31
IRFNA	3	8 (LA)	Table 5-31
N_2O_4/MON	2	2.3 (LA)	Table 5-31
LO_2	N/A	2.2 (LA)	Table 5-32
RP-1	II	3 (LB)	Table 5-30
JP-10	II	3J (LB)	Table 5-30
LH_2	N/A	2.1 (LB)	Table 5-33
N_2H_4 > 64%	II	8 (LC)	800[e] ft or 300[f] or footnote g *243.8[e] ft or 91.4[f] or footnote g*
Aerozine 50 (50% N_2H_4/50% UDMH)	I B	6.1 (LC)	800[e] ft or 300[f] or footnote g *243.8[e] ft or 91.4[f] or footnote g*
Methylhydrazine	I B	6.1 (LC)	800[e] ft or 300[f] or footnote g *243.8[e] ft or 91.4[f] or footnote g*
UDMH	I B	6.1 (LC)	Table 5-30
Ethylene Oxide	I A	2.3 (LD)	HD 1.1 QD[h] with TNT Equiv = 100%, or 800[e] ft or 300[e] ft *HD 1.1 QD[h] with TNT Equiv = 100%, or 243.8[e] m or 91.4[f] m*
Propylene Oxide	I A	3 (LD)	HD 1.1 QD[h] with TNT Equiv = 100%, or 800[e] ft or 300[e] ft *HD 1.1 QD[h] with TNT Equiv = 100%, or 243.8[e] m or 91.4[f] m*
Nitromethane	I C	3 (LE)	HD 1.1 QD[h] with TNT Equiv = 100%[i], or Table 5-30
HAN	2	8 (LE)	800[e] ft or Table 5-31 *243.8[e] m or Table 5-31*
XM-46 (HAN Monopropellant)	N/A	1.3C (LE)	800[e] ft or use HD 1.3 QD *243.8[e] m or use HD 1.3 QD*
Otto Fuel II	III B	9 (LE)	HD 1.1 QD[j] with TNT Equiv = 100%, or 150[k] ft or Table 5-30 *HD 1.1 QD[j] with TNT Equiv = 100%, or 45.7[k] m or Table 5-30*
Halogen Fluorides (ClF_3/ClF_5)	4	2.3 (LE)	Table 5-31
Liquid Fluorine	4	2.3 (LE)	Table 5-31
Nitrogen Trifluoride	4	2.3 (LE)	Table 5-31

Energetic Liquid	OSHA/NFPA Fuel[a] or Oxidizer[b] Class	DoD Storage Hazard Class	Minimum QD[c]
Nitrate Esters (e.g. NG, TMETN, DEGDN, TEGDN, BTTN)	N/A	1.1 D (LE)	HD 1.1 QD with TNT Equiv = 100%

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

OSHA = Occupational Safety and Health Administration; NFPA = National Fire Protection Association; H_2O_2 = hydrogen peroxide; IRFNA = inhibited red fuming nitric acid; N_2O_4 = nitrogen tetroxide; MON = mixed oxides of nitrogen; LO_2 = liquid oxygen; RP = rocket propellant; JP = jet propellant; LH_2 = liquid hydrogen; N_2H_4 = hydrazine; UDMH = unsymmetrical dimethylhydrazine; HD = hazard division; TNT = trinitrotoluene; HAN = hydroxyl ammonium nitrate; ClF_3 = chlorine trifluoride; ClF_5 = chlorine pentafluoride; NG = nitroglycerin; TMETN = trimethylolethane trinitrate; DEGDN = diethylene glycol dinatrate; TEGDN = triethylene glycol dinitrate; BTTN = butane-trio-trinitrate	
a	Flammable or combustible liquid classification index based on flash point and boiling point versus criteria as specified in 29 CFR 1910.106 and NFPA 400). Primary descriptor is a Roman numeral, possibly with an additional letter.
b	NFPA oxidizer classification index as described in NFPA 400, Code for the Storage of Liquid and Solid Oxidizers. Descriptor is an ordinary number.
c	Positive measures for spill containment/control shall be taken for isolated storage of energetic liquids in accordance with applicable OSHA and NFPA guidance (referenced in Tables 5-30. through 5-32.). For flammable energetic liquids and liquid oxidizers where only minimum blast or fragment distances are specified, applicable OSHA and/or NFPA guidance referenced in Tables 5-30 and 5-31., respectively, should also be used.
d	H_2O_2 solutions of concentration greater than 91% are NFPA Class 4 oxidizers.
e	Shall be used as a default value, unless otherwise hazard classified, when the material is packaged in small (non-bulk) shipping containers, portable ground support equipment, small aerospace flight vehicle propellant tanks, or similar pressure vessels that provide heavy confinement (burst pressure greater than 100 psi [690 kPa]).
f	Shall be used as a default value, unless otherwise hazard classified, when the material is packaged in small (non-bulk) shipping containers (DOT 5C or equivalent), portable ground support equipment, small aerospace flight vehicle propellant tanks, or similar pressure vessels providing a lower level of confinement (burst pressure less than or equal to 100 psi [690 kPa]) and if adequate protection from fragments is not provided from terrain, effective barricades, nets, or other physical means (lightweight building construction is not adequate). If protection from fragments is provided, use the IBD/PTRD "Protected" column of Table 5-33.
g	For large ready, bulk, or rest storage tanks (as defined in sections 5.30.20.7 e (3), (6) and (7) use Table 5-33.
h	Where there is a reasonable risk of vapor cloud explosion of large quantities (for example, in bulk tank storage).
i	Technical grade nitromethane in unit quantities of 55 gallons [208.2 liters] or less in DOT-approved containers listed in 49 CFR 173.202 may be stored as flammable liquids (Table 5-30) provided the following apply: 1. Packages are stored only one tier high. 2. Packages are protected from direct rays of the sun. Maximum storage life of 2 years, unless storage life tests indicate product continues to meet purchase specification. Such tests are to be repeated at 1-year intervals thereafter.

j	For underwater static test stands, when operated at hydrostatic pressure above 50 pounds per square inch gauge (psig) [345 kPa], or for propellant tanks or other vessels having burst pressures of greater than 100 psig [690 kPa] without acceptable pressure relief devices (unless otherwise hazard classified). For underwater test stands, the TNT equivalence (i.e., maximum credible event (MCE)) should include the total energetic liquids weight in all pumps and plumbing, as well as the weight of energetic liquids held in tankage (under the test cell hydrostatic pressure) unless acceptable mitigation measures such as fuel line detonation arrestors and/or fuel tank isolation/barricading are used (as determined by hazard analysis).
k	Should be used as a default value, unless otherwise hazard classified, when the material is packaged in small vehicle propellant tanks, small (non-bulk) shipping containers, portable ground support equipment, or similar pressure vessels that provide relatively heavy confinement (burst pressure between 50 – 100 psig [345 – 690 kPa]) without acceptable pressure relief devices.

5.32.21.3 Determination of Energetic Liquids Quantity.

a. The total quantity of energetic liquids in a tank, drum, cylinder, or other container shall be the net weight of the energetic liquids contained therein.

b. When storage containers are not separated from each other by the appropriate distance or are not so subdivided as to prevent possible accumulative involvement, the quantity shall be considered as the total of all such storage containers.

c. Quantity of energetic liquids in the associated piping shall be included to the points that positive means are provided for interrupting the flow through the pipe, or interrupting a reaction in the pipe in the event of an incident.

d. When the quantities of energetic liquids are given in gallons, the conversion factors given in Table 5-28 may be used to determine the quantity in pounds.

Table 5-28. Factors to Use When Converting Energetic Liquids Densities[a]

Item	Density (lb/gallon) *[kg/liter]*	Temperature degrees Fahrenheit (°F) *degrees Celsius [°C]*
ClF_5	14.8	77
	1.77	*25.0*
ClF_3	15.1	77
	1.81	*25.0*
Ethyl alcohol	6.6	68
	0.79	*20.0*
Ethylene oxide	7.4	51
	0.89	*10.6*
Fluorine (liquid)	12.6	-306
	1.51	*-187.8*
HAN Monopropellants	11.9	77
	1.43	*25.0*
HAN solution (25 to 95 wt %)	10.0 to 13.4	68
	1.20 to 1.61	*20.0*
	8.4	68

Item	Density (lb/gallon) *[kg/liter]*	Temperature degrees Fahrenheit (°F) *degrees Celsius [°C]*
N_2H_4	*1.01*	*20.0*
H_2O_2 (90%)	11.6	77
	1.39	*25.0*
JP-10	7.8	60
	0.93	*15.6*
LH_2	0.59	-423
	0.07	*-252.8*
LO_2	9.5	-297
	1.14	*-182.8*
Monomethylhydrazine (MMH)	7.3	68
	0.87	*20.0*
N_2O_4	12.1	68
	1.45	*20.0*
Nitrogen trifluoride	12.8	-200
	1.53	*-128.9*
Nitromethane	9.5	68
	1.14	*20.0*
Otto Fuel II	10.3	77
	1.23	*25.0*
Propylene oxide	7.2	32
	0.86	*0.0*
IRFNA	12.9	77
	1.55	*25.0*
RP-1	6.8	68
	0.81	*20.0*
UDMH	6.6	68
	0.79	*20.0*
UDMH/ N_2H_4	7.5	77
	0.90	*25.0*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Conversion of quantities of energetic liquids:
	English EQNs From gallons to lbs: lbs of energetic liquid = gallons*density of energetic liquid (lbs/gallon) From lb/gallon to kg/liter: 1 lb/gallon = 8.345 kg/liter
	Metric EQNs *From liters to kg: kg of energetic liquid = liters*density of energetic liquid (kg/liter)* *From kg/liter to lb/gallon: 1 kg/liter = 0.11983 lb/gallon*

5.32.21.4 Measurement of Separation Distances.

a. Separation distances shall be measured from the closest hazard source (containers, buildings, segment, or positive cutoff point in piping, whichever is controlling).

b. When buildings containing a small number of cylinders or drums are present or when quantities of energetic liquids are subdivided effectively, distances may be measured from the nearest container or controlling subdivision.

5.32.21.5 Hazard Classification of Energetic Liquids. The design and logistics of rocket systems sometimes require that consideration be given to permitting storage or operations involving energetic liquids in a storage structure containing solid explosives. Storage of energetic liquids shall be in accordance with the applicable DOT, OSHA, and fire safety regulations. Each new energetic liquid, or new non-bulk packaging configuration of an energetic liquid, developed by a NASA organization or adopted for NASA use, shall be examined and assigned a hazard classification in accordance with Department of Transportation Procedures.

5.32.21.5.1 The first element in the hazard classification nomenclature is the standard storage and transportation Compatibility Group (CG) designation. The alpha designations are the same as the CG designations for UN Hazard Class 1, with the same definitions. However, for storage and handling on NASA facilities, a CG may also be assigned to an energetic liquid in a Hazard Class other than Class 1. The absence of a CG indicates incompatibility with solid explosives.

5.32.21.5.2 The second element in the hazard classification nomenclature is a new Energetic Liquid Compatibility Group (ELCG) designation. The ELCG applies to mixed storage of energetic liquids or explosives components containing energetic liquids. The ELCG is specified in parentheses as the last element of the hazard classification. The ELCG designations and definitions are:

a. LA - Energetic liquids that are strong oxidizers, mainly of acidic character. These materials may cause or contribute to the combustion of other material, possibly resulting in serious flare fires or explosions. Includes, but is not limited to, nitrogen tetroxide and mixed oxides of nitrogen (MON), inhibited red fuming nitric acid (IRFNA), liquid oxygen (LO2), hydrogen peroxide (H2O2), and gels, slurries, or emulsions of the above.

b. LB - Energetic liquids that are readily combustible when exposed to, or ignited in the presence of an oxidizing agent, but that are not strong reducing agents. Some may be hypergolic with group LA materials. Includes, but is not limited to, hydrocarbons such as kerosenes and strained ring ramjet fuels; liquid hydrogen (LH2); and gels, slurries, or emulsions of the above.

c. LC - Energetic liquids that are readily combustible when exposed to, or ignited in the presence of an oxidizing agent, and are also strong reducing agents. These will likely be hypergolic with group LA substances. Includes, but is not limited to, hydrazines and other amines; and gels, slurries, or emulsions of the above.

d. LD - Energetic liquids that act mainly as combustible fuels, similar to groups LB and LC, when exposed to, or ignited in the presence of oxidizing agents but that may act as oxidizers in some combinations. They may be a monopropellant with the right

catalyst, or may be pyrophoric and ignite upon release to the atmosphere. Examples are ethylene and propylene oxides, and boranes.

e. LE - Energetic liquids having characteristics that do not permit storage with any other energetic liquid. They may react adversely with either fuels (reducing agents) or oxidizers. Examples are nitromethane, nitrate ester based formulations such as Otto Fuel II, liquid monopropellants containing hydroxyl ammonium nitrate (HAN), halogen fluorides (ClF3 and ClF5) and fluorine, and gels, slurries, or emulsions of these chemicals.

5.32.21.5.3 For mixing of energetic liquids:

5.32.21.5.3.1 Different energetic liquids in the same ELCG may be stored together.

5.32.21.5.3.2 ELCG-LE may not be mixed with other ELCG or dissimilar ELCG-LE.

5.32.21.5.3.3 Mixed storage is prohibited between energetic liquids of different ELCG designations with one exception. ELCG-LB and -LC should not be stored together, particularly when the majority of the material stored is ELCG-LB; however, mixed storage of ELCG-LB and -LC is permitted when operationally necessary.

5.32.21.5.4 As an example, for the 1.3C(LE) hazard classification for HAN-based liquid gun propellant XM-46:

5.32.21.5.4.1 “C”: indicates the propellant can be stored in the same magazine with CG-C solid propellants. Because CG-C and CG-D can be mixed, CG-D high explosive projectiles could also be stored with the energetic liquid gun propellant.

5.32.21.5.4.2 “LE”: indicates that hydrocarbon fuel (e.g., JP-10), which is an ELCG-LB, would not be permitted in this storage scenario, because its ELCG-LB indicates incompatibility with ELCG-LE.

5.32.21.6 The QD criteria described below include separation requirements for bulk quantities and, in some cases, minimum distances for pressure vessels and other commercial packaging. If the hazards of a particular new packaging configuration are not adequately addressed by the separations prescribed in the following tables, a different minimum distance may be assigned during the hazard classification process and indicated parenthetically, in hundreds of feet, as the first element of the hazard classification. For example, if a new liquid oxygen pressure vessel configuration is hazard classified: “(10)2.2(LA),” a minimum distance of 1,000 ft. would apply for IBD and PTRD, rather than the minimum distance specified in Table 5-27.

5.32.21.7 QD standards. Since many energetic liquids are not classified as UN Class 1 explosives, conventional QD storage criteria do not generally apply to these materials. Thus, the implementation of QD criteria for energetic liquids is based on an independent determination of the predominant hazard presented by the material in the storage environment. The following standards are applicable to energetic liquids used for propulsion or operation of rockets and other related devices.

a. The minimum distance requirements provided in Tables 5-27, 5-30, 5-31, 5-32, and 5-33 shall be followed for storage of bulk quantities, and in some cases, pressure vessels and other commercial packaging of energetic liquids.

b. In general, storage of different energetic liquids shall be separated by the minimum distance required by the material requiring the greatest distance.

c. In addition, positive measures shall be taken to control the flow of energetic liquids in the event of a leak or spill, in order to prevent possible fire propagation or accumulation of flammable liquids near other storage, and/or to prevent mixing of incompatible energetic liquids (except for specific hazardous locations as identified below in this section). Explosives equivalence applies for some materials as indicated in Tables 5-27 and 5-29. Fragment hazards govern for some materials in certain packaging configurations.

d. For specific hazardous locations as defined below in this section, equivalent explosive weights may apply. If so, consult Tables 5-27 and 5-29 with the combined energetic liquids weight subject to mixing and use distances found in Tables 5-9 and 5-10 Enter the equivalent explosive weight in Table 5-9 or 5-10 QD standards for other conditions and equivalent explosive weights for any combination not contained in Table 5-27 or 5-29 shall be determined by the controlling NASA Center.

Table 5-29. Energetic Liquid Equivalent Explosives Weights[a, b, c, d, e]

Energetic Liquids	TNT Equivalence	
	Static Test Stands	Range Launch
LO_2/LH_2	See footnote f	See footnote f
LO_2/LH_2 + LO_2/RP-1	Sum of (see footnote f for LO_2/LH_2) + (10% for LO_2/RP-1)	Sum of (see footnote f for LO_2/LH_2) + (20% for LO_2/RP-1)
LO_2/RP-1	10%	20% up to 500,000 lbs plus 10% over 500,000 lbs *20% up to 226,795 kg* *plus 10% over 226,795 kg*
IRFNA/UDMH[g]	10%	10%
N_2O_4/UDMH + N_2H_4[g]	5%	10%
N_2O_4 liquid oxidizer + polybutadiene-acrylic acid-acrolyonitrile (PBAN) solid fuel (Hybrid propellants)	15%[h]	15%[h]
Nitromethane (alone or in combination)	100%	100%
Otto Fuel II	100%[i]	
Ethylene Oxide	100% [j]	100% [j]

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	The percentage factors given in this table are to be used to determine equivalent explosive weights of energetic liquids mixtures at static test stands and range launch pads when such energetic liquids are located aboveground and are unconfined except for their tankage. Other configurations shall be considered on an individual basis to determine equivalent explosive weights.
b	The equivalent explosive weight calculated by the use of this table shall be added to any non-nuclear explosive weight aboard before distances can be determined from Tables 5-10 and 5-11.
c	These equivalent explosive weights apply also for these substitutions: 1. Alcohols or other hydrocarbons for RP-1. 2. H_2O_2 for LO_2 (only when LO_2 is in combination with RP-1 or equivalent hydrocarbon fuel). 3. Monomethylhydrazine (MMH) for N_2H_4, Unsymmetrical Dimethylhydrazine (UDMH), or combinations of
d	For quantities of energetic liquids up to but not over the equivalent explosive weight of 100 lbs [45.4 kg] of explosives, the distance shall be determined on an individual basis by the applicable NASA Center ESO. All personnel and facilities, whether involved in the operation or not, shall be protected by operating procedures, equipment design, shielding, barricading, or other suitable means.
e	Distances less than intraline are not specified. Where a number of prepackaged energetic liquid units are stored together, separation distance to other storage facilities shall be determined on an individual basis by the applicable NASA Center ESO, taking into consideration normal hazard classification procedures.
f	For siting launch vehicles and static test stands, equivalent explosive weight is the larger of: 1. The weight equal to $8W^{2/3}$ [$4.13Q^{2/3}$] where W [Q] is the weight of LO_2/LH_2; or 2. 14% of the LO_2/LH_2 weight. For these calculations, use the total weight of LO_2/LH_2 present in the launch vehicle, or the total weight in test stand run tankage and piping for which there is no positive means to prevent mixing in credible mishaps. When it can be reliably demonstrated that the MCE involves a lesser quantity of energetic liquids subject to involvement in a single reaction, the lesser quantity may be used in determining the equivalent explosive weight. When siting is based on a quantity less than the total energetic liquids present, the MCE and associated explosive yield analysis must be documented in an approved site plan.
g	These are hypergolic combinations.
h	The equivalent explosive weight of the hybrid rocket system N_2O_4 liquid oxidizer combined with PBAN solid fuel was evaluated as 15% for an explosive donor accident scenario, 5% for a high-velocity impact scenario, and less than 0.01% (negligible) for static mixing (tower drop) failures (Air Force Rocket Propulsion Laboratory AFRPL-TR-67-124).
i	See footnote j of Table 5-27.
j	See footnote h of Table 5-27.

Table 5-30. QD Criteria for OSHA/NFPA Class I – III Flammable and Combustible Energetic Liquids Storage in Detached Buildings or Tanks[a, b]

Quantity	IBD/PTRD	ILD/Aboveground Intermagazine Distance (IMD)
	(ft)	(ft)
	[m]	*[m]*
Unlimited[C]	*50*[d,e]	Footnote f
	15.2[d,e]	

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Other guidelines for diking, tank or container construction, tank venting, and facility construction apply (except for Class III B combustible liquids, e.g., Otto Fuel II). Refer to 29 CFR 1910.106 and NFPA 30 for further guidance on liquid storage and fire protection.
b	Refer to 29 CFR 1910.106 and NFPA 30 for definition and explanation of OSHA/NFPA classification of flammable and combustible liquids.

c	Guidelines on interior storage configuration (for container storage inside buildings) also apply with these exceptions: 1. If the storage building is located at least 100 ft [30.5 m] from any exposed building (under the direct jurisdiction of a fire protection organization) or property line; or 2. If the storage building is located at least 200 ft [61 m] from any exposed building (not under the direct jurisdiction of a fire protection organization) or property line; or For combustible liquids that will not exhibit sustained burning in bulk form, e.g., Otto Fuel II, as determined through ASTM D 92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup or comparable testing. Refer to 29 CFR 1910.106 and NFPA 30 for further guidance on liquid storage and fire protection.
d	For container storage inside of a building, IBD/PTRD may be less than 50 ft [15.2 m] (to a minimum of 10 ft [3.05 m]) if the storage building is constructed of fire-resistive exterior walls having an NFPA fire resistance rating of 2 hours or more, according to NFPA 251.
e	For large tank storage, QD may be 25 ft [7.6 m] for tank capacities up to 100,000 gallons [378,541 liters], and 37.5 ft [11.4 m] for capacities between 100,001 gallons [378,545 liters] and 500,000 gallons [1,892,706 liters].
f	For flammable liquids container storage inside of a building, ILD/aboveground IMD is 50 ft [15.2 m] (except as in footnote d), or for adjacent incompatible oxidizer storage, distances specified for energetic liquid oxidizers (Table 5-31) or oxygen (Table5-32). For flammable liquids storage in fixed or large portable tanks, ILD/aboveground IMD is either (1) for compatible energetic liquids, equal to one-sixth of the sum of the diameters of the two adjacent tanks, or distances specified in footnote e for adjacent container storage inside of a building; or (2) for adjacent incompatible oxidizer storage, distances specified for energetic liquid oxidizers (Table5-31) or oxygen (Table5-32). Earth-covered magazines (ECMs) may be used to their physical capacity for storing flammable energetic liquids provided they comply with the construction and siting requirements for Hazard Division 1.1. ECMs shall be sited for a minimum of 100 lbs [45.4 kg] of HD 1.1 items using Tables 5-12 and 5-13.

Table 5-31. QD Criteria for Energetic Liquid Oxidizer (excluding LO_2) Storage in Detached Buildings or Tanks[a,b]

NFPA Oxidizer Class[c]	Quantity	IBD/PTRD/ILD/ Aboveground IMD
	(lbs)	(ft)
	[kg]	*[m]*
2	up to 600,000	50
	up to 227,154	*15.2*
3	up to 400,000	75
	up to 181,436	*22.9*
4[d,e,f]	≤ 50	75
	< 22.7	*15.2*
	70	76
	31.8	*23.1*
	100	79
	45.4	*24.1*
	150	84
	68.0	*25.7*
	200	89
	90.7	*27.2*
	300	98
	136.1	*29.9*

NFPA Oxidizer Class[c]	Quantity	IBD/PTRD/ILD/ Aboveground IMD
	(lbs)	(ft)
	[kg]	*[m]*
	500	114
	226.8	*34.8*
	700	128
	317.5	*39.0*
	1,000	147
	453.6	*44.7*
	1,500	175
	680.4	*53.2*
	2,000	200
	907.2	*60.9*
	3,000	246
	1,360.8	*74.9*
	5,000	328
	2,268.0	*100.0*
	7,000	404
	3,175.1	*123.0*
	10,000	510
	4,535.9	*155.4*
	15,000	592
	6,803.9	*180.4*
	20,000	651
	9,071.8	*198.5*
	30,000	746
	13,607.7	*227.3*
4[d,e,f]	50,000	884
	22,679.5	*269.5*
	70,000	989
	31,751.3	*301.5*
	100,000	1,114
	45,359.0	*339.5*
	150,000	1,275
	68,038.5	*388.6*
	200,000	1,404
	90,718.0	*427.8*
	300,000	1,607
	136,077.0	*489.7*
	500,000	1,905
	226,795.0	*580.6*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	QD requirements do not apply to storage of NFPA Class 2 and 3 oxidizers in approved fixed tanks.

b	Other requirements for interior storage configuration, building construction, diking, container materials, facility venting, etc. also apply. Refer to NFPA 400 for further guidance on oxidizer storage and fire protection.
c	Refer to NFPA 400 for definition and explanation of NFPA classification of oxidizers.
d	Multiple tanks containing NFPA Class 4 oxidizers may be located at distances less than those specified in this table; however, if the tanks are not separated from each other by 10% of the distance specified for the largest tank, then the total contents of all tanks shall be used to calculate distances to other exposures.
e	The following equations may be used to determine distance/weights for other quantities: English EQNs (Quantity (W) in lbs, distance in ft; ln is natural logarithm, exp [x] is e^x) W ≤ 10,000 lbs: Distance = $149.3*W^{(-0.41+0.059*\ln(W))}$ W > 10,000 lbs: Distance = $24*W^{1/3}$ Distance > 75 ft: W = exp[-313.18 + 206.53*(ln(Distance)) –49.968*(ln(Distance))2 + 5.5354*$(\ln(\text{Distance}))^3$– 0.2119*$(\ln(\text{Distance}))^4$] *Metric EQNs (Quantity (W) in kg, distance in m; ln is natural logarithm, exp [x] is e^x)* *W ≤4,535.9 kg: Distance = $34.2*W^{(-0.317+0.059*\ln(W))}$* *W > 4,535.9 kg: Distance = $9.52*W^{1/3}$* *Distance > 22.9 m: W = exp[-130.32+108.79*(ln(Distance)) –32.587*$(\ln(\text{Distance}))^2$ + 4.3313*$(\ln(\text{Distance}))^3$– 0.21111*$(\ln(\text{Distance}))^4$]*
f	NFPA 400 requires sprinkler protection to be provided for storage of greater than 2,000 lbs [907.2 kg] of NFPA Class 4 oxidizers inside of a building.

Table 5-32. QD Criteria for LO_2 Storage in Detached Buildings or Tanks[a,b]

Quantity	IBD/PTRD	ILD/Aboveground IMD
	(ft)	(ft)
	[m]	*[m]*
Unlimited[c]	100	100[d]
	30.5	*30.5*[d]

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Distances do not apply where a protective structure having an NFPA fire resistance rating of at least 2 hours interrupts the line of sight between the oxygen system and the exposure. Refer to 29 CFR 1910.104 and NFPA 55 for further guidance.
b	Additional guidelines relating to equipment assembly and installation, facility design (diking), and other fire protection issues also apply. Refer to 29 CFR 1910.104 and NFPA 55 for further guidance.
c	QD is independent of oxygen quantity.
d	Minimum ILD/IMD distance between adjacent compatible energetic liquids storage is 50 ft [15.2 m].

Table 5-33. QD Criteria for LH_2 and Bulk Quantities of Hydrazines[a]

Propellant Weight (W)	IBD/PTRD		ILD/Aboveground IMD[f, g]
	Unprotected[b, c]	Protected[d, e]	
(lbs)	(ft)	(ft)	(ft)

Propellant Weight (W)	IBD/PTRD		ILD/AbovegroundIMD[f, g]
	Unprotected[b, c]	Protected[d, e]	
[kg]	*[m]*	*[m]*	*[m]*
≤ 100	600	80	30
≤ 45.4	*182.9*	*24.4*	*9.1*
150	600	90	34
68	*182.9*	*27.4*	*10.3*
200	600	100	37
90.7	*182.9*	*30.4*	*11.2*
300	600	113	42
136.1	*182.9*	*34.4*	*12.7*
500	600	130	49
226.8	*182.9*	*39.5*	*14.6*
700	600	141	53
317.5	*182.9*	*42.9*	*15.9*
1000	600	153	57
453.6	*182.9*	*46.5*	*17.2*
1500	600	166	62
680.4	*182.9*	*50.7*	*19*
2000	600	176	66
907.2	*182.9*	*53.7*	*19.9*
3000	600	191	72
1360.8	*182.9*	*58.2*	*21.5*
5000	600	211	79
2268	*182.9*	*64.1*	*23.7*
7000	600	224	84
3175.1	*182.9*	*68.3*	*25.3*
10000	603	239	90
4535.9	*183.9*	*72.9*	*27*
15000	691	258	97
6803.9	*210.5*	*78.5*	*29*
20000	760	272	102
9071.8	*231.7*	*82.7*	*30.6*
30000	870	292	110
13607.7	*265.2*	*89*	*32.9*
50000	1032	321	120
22679.5	*314.5*	*97.6*	*36.1*
70000	1154	341	128
31751.3	*351.8*	*103.8*	*38.4*
100000	1300	364	136
45359	*396.2*	*110.7*	*41*
150000	1488	391	147
68038.5	*453.6*	*119.1*	*44.1*

Propellant Weight (W)	IBD/PTRD		ILD/AbovegroundIMD[f, g]
	Unprotected[b, c]	Protected[d, e]	
200000	1637	412	155
90718	*499.2*	*125.5*	*46.4*
300000	1800	444	166
136077	*548.6*	*135.1*	*50*
500000	1800	487	183
226795	*548.6*	*148.2*	*54.8*
700000	1800	518	194
317513	*548.6*	*157.6*	*58.3*
1,000,000[h]	1800	552	207
453,590.0 [h]	*548.6*	*168.1*	*62.2*
1,500,000 [h]	1800	594	223
680,385.0 [h]	*548.6*	*180.8*	*67.8*
2,000,000 [h]	1800	626	235
907,180.0 [h]	*548.6*	*190.4*	*70.5*
3,000,000 [h]	1800	673	252
1,360,770.0 [h]	*548.6*	*204.7*	*75.8*
5,000,000 [h]	1800	737	276
2,267,950.0 [h]	*548.6*	*224.2*	*83*
7,000,000 [h]	1800	782	293
3,175,130.0 [h]	*548.6*	*237.9*	*88*
10,000,000 [h]	1800	832	312
4,535,900.0 [h]	*548.6*	*253.3*	*93.7*

(Reference: DoD 6055.09, March 12, 2012)

NOTES:

a	Positive measures shall be taken to prevent mixing of hydrogen or hydrazines and adjacent oxidizers in the event of a leak or spill.
b	Distances are necessary to provide reasonable protection from fragments of tanks or equipment that are expected to be thrown in event of a vapor phase explosion.
c	English EQNs (W in lbs, Distance in ft) W ≤ 10,000 lbs: Unprotected Distance = 600 ft 10,000 < W ≤ 265,000 lbs: Unprotected Distance = $28*W^{1/3}$ W > 265,000 lbs: Unprotected Distance = 1,800 ft 603 ft < Unprotected Distance < 1,798 ft: W = (Unprotected Distance/28)^3
	Metric EQNs (W in kg, Distance in m) *W ≤ 4,535.9 kg: Unprotected Distance = 182.9 m* *4,535.9 kg <W ≤ 120,201.4kg: Unprotected Distance = $11.11*W^{1/3}$* *W > 120,201.4 kg: Unprotected Distance = 548.6 m* *183.9 m ≤ Unprotected Distance < 548.2 m: W = (Unprotected Distance/11.11)^3*
d	The term “protected” means that protection from fragments is provided by terrain, effective barricades, nets, or other physical means.

e	Distances are based on the recommended IBD given in U.S. Department of the Interior, Bureau of Mines Report 5707, and extrapolation of the 2 calories/square centimeter data on the 1% water vapor curve.	
	English EQNs (W in lbs, Distance in ft; ln is natural logarithm, exp [x] is e^x)	
	W ≤ 100 lbs:	Protected Distance = 80 ft
	100 lbs <W:	Protected Distance = -154.1 + 72.89*[ln(W)] – 6.675*[ln(W)]^2 + 0.369*[ln(W)]^3
	80 ft ≤ Protected Distance:	W = exp [311.367 – 215.761*(ln(protected distance)) + 55.1828*(ln(protected distance))^2 – 6.1099*(ln(protected distance))^3 + 0.25343*(ln(protected distance))^4]
	Metric EQNs (W in kg, Distance in m; ln is natural logarithm, exp [x] is e^x)	
	W ≤ 45.4 kg:	*Protected Distance = 24.4 m*
	45.4 kg <W:	*Protected Distance = -30.62 + 19.211* [ln(W)] – 1.7678*[ln(W)]^2 + 0.1124* [ln(W)]^3*
	24.4 m ≤ Protected Distance:	*W = exp [122.38 – 108.8094*(ln(protected distance)) + 35.5517*(ln(protected distance))^2 – 4.9055*(ln(protected distance))^3 + 0.25343*(ln(protected distance))^4]*
f	ILD/aboveground IMD distances in this column apply for adjacent compatible (ELCG LB or LC) storage; for adjacent incompatible (other ELCG) storage, use IBD distances shown in previous columns. ECMs may be used to their physical capacity for storing hydrogen provided they comply with the construction and siting requirements for Hazard Division 1.1. ECMs shall be sited for a minimum of 100 lbs [45.4 kg] of HD 1.1 items using Tables 5-11 and 5-12.	
g	Distances are 37.5% of "protected" column.	
h	Extrapolations above 1,000,000 lbs [453,590 kg] extend well outside data included in the Bureau of Mines, Department of the Interior Report No. 5707, dated 1961, from which the original QD tables were derived; however, they are supported by independent calculations and knowledge of like phenomena.	

Table 5-34. Recommended Distances between Bulk Gaseous Oxygen Storage and Flammable Gases Stored Above Ground

	Flammable Gas	Quantity	Distance	
			Ft.	m
NFPA 55	Liquefied hydrogen	Any	75	22.5
	Other liquefied gases	≤ 1000 gal (3785 L)	25	7.5
		≥ 1000 gal (3785 L)	50	15
29 CFR 1910.104	Nonliquefied or dissolved gases	≤ 25 000 ft^3 (708 m^3) (NTP)	25	7.5
		> 25 000 ft^3 (708 M^3) (NTP)	50	15
	Compressed, liquefied, and others in low-pressure gas holders	< 500 ft^3 (142 m^3)	50	15
		≥ 5000 ft^3 (142m^3)	90	27

e. Specific Hazardous Locations. Aside from the fact that the energetic liquids differ from each other, as explained for the above groups, the predominant hazard of the

individual energetic liquids can vary depending upon the location of the energetic liquid storage and the operations involved. In order of decreasing hazard, these conditions are:

(1) Launch Pads. These involve research, development, testing, and space exploration launchings. Operations at these facilities are very hazardous because of the proximity of fuel and oxidizer to each other, the frequency of launchings, lack of restraint of the vehicle after liftoff, and the possibility of fallback with resultant dynamic mixing on impact. To compute the equivalent explosive weight for the launch pad, use Table 5-27 with the combined energetic liquids weight in the launch vehicle tanks and any energetic liquids in piping that are subject to mixing, except as indicated in section 5.32.20.8(e)(4).

(2) Static Test Stands. Although these can involve experimental operations they tend to be less hazardous because the units are restrained and are subject to better control than launch vehicles. As with launch pads, the proximity of fuel and oxidizer presents a significant hazard. To reduce this hazard, tankage should be separated and remotely located from the static test stand. The equivalent explosive weights of Table 5-29 shall be used, with the combined energetic liquids weight subject to mixing as determined by hazard analysis. The hazard analysis (MCE) shall include assessment of a test article explosion with associated fragment, overpressure, and thermal flux effects. The amount of energetic liquids held in run tanks can be excluded from consideration if the test stand meets the following criteria:

(a) All tanks are American Society of Mechanical Engineers (ASME) certified and designed and maintained in accordance with the ASME Code.

(b) For cryogenic propellants, all tanks are constructed with double wall jacketing.

(c) The configuration of the test stand is such that the thrust measuring structure load cell (heavily built structure) is between the engine and the run tanks so as to prevent fragments from puncturing the tanks in case of engine malfunction.

(d) Each feed line contains two remotely operated valves to shut off energetic liquids flow in the event of a malfunction.

(3) Ready Storage. This storage is relatively close to the launch and static test stands; normally it is not involved directly in feeding the engine as in the case with run tankage, which is an integral part of all launch and test stand operations. The equivalent explosive weights of Table 5-29 shall be used with the combined energetic liquids weight subject to mixing if the facility design does not guarantee against fuel and oxidizer mixing and against detonation propagation to, or initiation at, the ready storage facility when a mishap occurs at the test stand, on the ground at the launch pad, or at the ready storage areas. Otherwise, fire and fragment hazards shall govern (Tables 5-27, 5-30, 5-31, 5-32, and 5-33).

(4) Cold-flow Test Operations. Fire and fragment hazards shall govern (Tables 5-27, 5-30, 5-31, 5-32, and 5-33) if the design is such that the system is closed except for approved venting, the system is completely airtight, fuel and oxidizer never are

employed concurrently, and each tank has a completely separate isolated system and fitting types to preclude intermixing, and the energetic liquids are of required purity.

(5) Otherwise, explosives equivalents shall be used with the combined energetic liquids weight.

(6) Bulk Storage. This is the most remote storage with respect to launch and test operations. It consists of the area, tanks, and other containers therein, used to hold energetic liquids for supplying ready storage and, indirectly, run tankage where no ready storage is available. Fire and fragment hazards govern (Tables 5-27, 5-30, 5-31, 5-32, and 5-33) except in special cases as indicated in Tables 5-27 and 5-29.

(7) Rest Storage. This is temporary-type storage and most closely resembles bulk storage. It is a temporary parking location for barges, trailers, tank cars, and portable hold tanks used for topping operations when these units actually are not engaged in the operation; and for such vehicles when they are unable to empty their cargo promptly into the intended storage container. Fire and fragment hazards govern (Tables 5-27, 5-30, 5-31, 5-32, and 5-33) except in special cases as indicated in Tables 5-27 and 5-29. The transporter becomes a part of that storage to which it is connected during energetic liquids transfer.

(8) Run Tankage (Operating Tankage). This consists of the tank and other containers and associated piping used to hold the energetic liquids for direct feeding into the engine or device during operation. The contents of properly separated "run tanks" (operating tankage) and piping are normally considered on the basis of the pertinent hazards for the materials involved, except for quantities of incompatible materials that are or can be in a position to become mixed. Equivalent explosive weights shall be used (Table 5-29) for quantities of such materials subject to mixing unless provisions above are satisfied.

(9) Pipelines. A 25-foot clear zone to inhabited buildings shall be maintained, as a minimum, on each side of pipelines used for energetic liquids (excluding flammable or combustible liquids that exhibit normal fire hazards such as RP-1, Hydrocarbon Turbine/Ramjet Fuel (JP-10), and Otto Fuel II). Tables 5-27, 5-31, 5-32, and 5-33 apply, as appropriate.

5.32.21.8 Contaminated Energetic Liquids.

a. Caution shall be exercised in the storage and handling of contaminated energetic liquids. Such contamination may increase the degree of hazard associated with the energetic liquids.

b. Energetic liquids known to be contaminated or in a suspect condition shall be isolated and provided separate storage from all other energetic liquids pending laboratory analysis for verification of contamination and disposition requirements, if any.

5.33 Motor Vehicle Transportation Requirements

5.33.1 All motor vehicle shipments are governed by DOT and shall comply with DOT, State, and municipal regulations.

5.33.2 Vehicles designated for explosives transportation shall be inspected using DD Form 626 or equivalent by the vehicle operator. The records shall be maintained for a minimum of one year.

5.33.3 Explosives shall not be transported in any portion of the vehicle occupied by personnel.

5.33.4 Motor vehicles used for transporting explosives shall meet the following requirements:

a. Special precautions shall be taken to avoid ignition of the material by the exhaust of the transporting vehicle.

b. Coverings shall be noncombustible or flame proof material when used.

c. Coverings shall be secured.

d. Two (2) extinguishers rated at a minimum of 2A:10BC shall be carried on the vehicle, one mounted externally by the driver's door.

e. Explosives shall be secured to prevent shifting during transit.

f. When carrying explosives, vehicles shall not be left unattended unless they are parked in a properly designated area.

g. When carrying explosives, brakes shall be set and wheels chocked when an operator leaves the vehicle.

h. EEDs shall always be transported in their packaged configuration.

i. Explosives shall not be grounded to the transport vehicle.

5.33.5 Placarding of vehicles transporting explosives shall be in accordance with DOT regulations.

5.34 Surface, Air, and Water Transportation and Shipment Requirements

5.34.1 The transportation and shipment of explosives by rail, air, vessel, and public highway shall comply with DOT regulations CFR Title 49 Parts 172 through 179.

5.34.2 Those transported and shipped by air shall comply with International Civil Aviation Organization (ICAO) "Technical Instructions for the Safe Transport of Dangerous Goods by Air" and The International Air Transport Association (IATA) "Dangerous Goods Regulations".

5.35 Explosives Handling Equipment

5.35.1 Specification, operation, and maintenance of explosives handling equipment shall be in accordance with this standard, current OSHA and NFPA regulations and operator's manual.

5.35.2 Powered equipment (battery and/or gasoline) and its use in explosives locations shall comply with current OSHA and NFPA standards and be appropriately labeled for ready identification.

5.35.3 Explosives handling equipment shall not be stored in buildings containing explosives.

5.36 Refueling Procedures

Gasoline powered equipment shall be refueled at a minimum 90 ft. from an explosives facility.

5.37 Storage of Gasoline Powered Equipment

Gasoline powered equipment shall not be stored in buildings containing explosives or on explosives loading docks where explosives are present. A central storage located at an approved safe distance and at least 50 ft. from buildings is preferred.

5.38 Storage of Battery Powered Equipment

When necessary for efficient operation, battery-powered explosives handling equipment permitted for use in the building or magazines containing explosives materials may be temporarily stored in magazines containing packaged explosives provided the following conditions are met:

5.38.1 Periods of idle storage do not exceed 4 days.

5.38.2 After each workday, equipment shall be inspected and removed from the building if hot brakes, leaking oil, or fluid are found to be present.

5.38.3 Battery cables shall not be disconnected in explosives storage locations due to the possible arcing when terminals separate.

5.38.4 Equipment shall be packed and secured at the maximum distance from the explosives.

5.38.5 Equipment shall not be stored in an operating building containing explosives because of the increased hazards of loose or exposed explosives.

5.39 5.39 Exceptions for Model Rocket Motors

5.39.1 Applicability

5.39.1.1 This section shall apply to the subset of model rocket motors that satisfy all of the following:

a. Ignited by electrical means using the manufacturer’s intended ignition system(s).

b. Contain no more than 2.2 ounces (62.5 grams) of propellant material.

c. Produce less than 17.92 pounds seconds (80 newton-seconds) of total impulse with thrust duration not less than 0.050 second.

d. Constructed such that all the chemical ingredients are preloaded into a cylindrical paper or similarly constructed nonmetallic tube that will not fragment into sharp, hard pieces.

e. Designed so they will not burst under normal conditions of use, are incapable of spontaneous ignition, and do not contain any type of explosive or pyrotechnic warhead other than a parachute or recovery-system activation charge.

f. Used in the manner for which the manufacturer designed it (e.g. only in model rockets, not as an igniter for NASA experimental testing).

g. Manufactured and certified in accordance with NFPA 1125 chapter 8.

5.39.1.2 Any model rocket motor that does not satisfy these requirements shall adhere to the requirements for explosives in this standard.

5.39.2 Storage

5.39.2.1 Model rocket motors shall be treated and stored as Class 4.1 flammable materials in accordance with the packaging requirements in Department of Transportation Special Permit 7887 (DOT-SP 7887).

5.39.2.2 The minimum storage requirements of applicable model rocket motors shall entail placement inside a flammable storage cabinet.

5.39.2.3 Model rocket motors shall not be stored with ignitors installed.

5.39.3 Licensing

Explosive licensing requirements of this document do not apply.

5.39.4 Transportation

5.39.4.1 Model rocket motors transported by vehicles shall comply with packaging specifications defined by DOT-SP 7887.

5.39.4.2 Transportation of model rocket motors shall be done by an individual of at least 18 years of age trained in the hazards associated with model rocket motors.

5.39.5 Use

The installation and use of model rocket motors shall conform to all local, state, and federal regulations in addition to the manufacturer’s instructions.

5.39.6 Training and Medical Requirements

When using model rocket motors applicable to section 5.39, individuals shall be exempt from the training and physical requirements of this document.

APPENDIX A. SITE PLANNING GUIDANCE

A.1 Purpose and/or Scope

The purpose of this non-mandatory appendix is to provide guidance and is made available in the reference documents listed below.

A.2 Definitions

Site Planning Process: The process of performing and documenting an analysis of planned and existing facilities and operations involving explosives, energetic liquids, and pyrotechnics (EELP) or occurring within the hazard zones created by EELP. The process may include evaluations of blast, fragment, thermal flux, and glass breakage hazards; protective construction; grounding, bonding, and lightning protection systems (LPS); electrical installations; natural or man-made terrain features; or other operations or local requirements.

A.3 General Guidelines

These evaluations should be completed as early as possible in the facility design review process. Effective site planning relies heavily on explosives safety standards but it also incorporates survivability and operational considerations and economic, security, environmental, and legal criteria to meet the goals and needs of the NASA community. (Ref. NPR 8820.2)

A.4 Detailed Guidelines

A.4.1 Site Plan Contents. Provide specific information on a proposed project and the results of the above analysis.

A.4.2 When to perform a Site Plan analysis

A.4.2.1 New Potential Explosives Site (PES) or Exposed Site (ES), which includes new construction for the manufacturing, handling, storage, maintenance, EELP waste treatment, or testing.

A.4.2.2 When major modifications are planned for existing facilities used for the purposes above and the modifications involve:

A.4.2.2.1 The introduction of a new or additional hazard (i.e., people or EELP causing a reduction of explosives limits in adjacent structures).

A.4.2.2.2 Increased net explosives weight (NEW) above the previously sited quantity.

A.4.2.2.3 When planned facilities or operations (ES not involving EELP) are exposed to blast, fire or fragment hazards due to changes in operations or facility usage.

A.4.2.2.4 When a reasonable doubt exists regarding possible exposure hazards.

A.4.2.2.5 When an existing facility has never had formal siting approval or the approved site plan cannot be located.

A.4.2.2.6 When establishing facilities for intentional detonation.

A.4.2.2.7 NEW quantity is more than amount authorized for “license” facility.

A.4.3 The site plan should include:

A.4.3.1 Exact distances between the closest wall or corner of the facility or explosives item, whichever is controlling, and the appropriate PES or ES.

A.4.3.2 Other facilities

A.4.3.3 Firefighting water towers or reservoirs should be located at a minimum distance determined by the formula $d = 40W^{1/3}$, where d is the distance in feet and W is the explosives weight in pounds.

A.4.3.4 Facility boundaries

A.4.3.5 Public traffic routes

A.4.3.6 Electrical transmission and distribution lines

A.4.3.7 Electrical substations

A.4.3.8 Identify all other facilities, including:

A.4.3.8.1 Occupancy (how many, how often);

A.4.3.8.2 Use (type of support provided and relationship to new or to-be-modified facility); and

A.4.3.8.3 The QD requirements within the inhabited building distance (IBD) arc of the new or to-be-modified facility.

A.4.3.9 List NEW and hazard/division (HD) with breakdown by room and bay, if appropriate.

A.4.3.10 The NEW and HD of the EELP items in other facilities encompassed by the IBD of the new or to-be-modified facility.

A.4.3.11 The NEW, classes, and divisions of the EELP items in facilities having IBDs that include the new or to-be-modified facility.

A.4.3.12 Anticipated personnel limits for the new or to-be-modified facility. A breakdown by room or bay should be provided.

A.4.3.13 A brief description of the EELP or non-EELP analysis to be performed in each facility.

A.4.3.14 Electromagnetic radiation restrictions, requirements and safe separation distances from dangerous levels of extraneous electricity, fields around high tension electrical wires, and RF transmitters shall be identified when electro-explosive devices (EED) are involved.

A.4.3.15 Vapor dispersion should be considered for systems involving energetic liquids. Conduct a risk analysis to determine the controls needed to manage the hazard.

A.4.3.16 Fencing and Placarding Restricted Areas. Fencing required for security or other purposes should not be placed closer to magazines than intermagazine distance (IMD), nor closer to explosives operating buildings than intraline distance (ILD).

A.4.3.17 A glass breakage assessment.

A.4.3.18 Detailed drawings of the Lightning Protection System.

A.4.3.19 The introduction of a new or additional hazard (i.e., people or EELP causing a reduction of explosives limits in adjacent structures).

APPENDIX B. HAZARDS OF ELECTROMAGNETIC RADIATION (EMR) TO EEDS

B.1 Purpose and/or Scope

This appendix is designed to preclude inadvertent EED initiation from EMR.

B.1.1 The requirements in this section are designed to preclude inadvertent EED initiation from EMR.

B.1.1.1 Calculations are valuable for evaluating a specific device and emitter; however, calculations can quickly become a difficult task for large numbers of devices. The following guidance may be used in lieu of specific calculations.

B.1.1.2 Maintaining a safe separation distance between the emitter and the EED provides protection. This distance is a factor of the effective radiated power (ERP) and frequency of the emitter. ERP is a product of the transmitter power and the gain of the transmitting antenna. Antenna gain is a measure of the power channeled by a directional antenna. It is usually provided in decibels (dB). Sometimes it is provided as a unit less number, G_t. Use the following formula to convert between G (dB) and G_t.

$G_t = \log^{-1} [G\ (dB)/10] = 10^{[G\ (dB)/10]}$
Frequency is measured in hertz (Hz) or cycles per second.

B.1.1.3 Transmitter power, P_t, is expressed in watts (W). If a transmitter is pulsed, it will have both a peak and average P_t. Generally, peak P_t is the best number to use when determining ERP. However, pulsed systems with small pulse widths (less than 1 millisecond) may be more accurately represented by average power.

B.1.1.4 Table B-1 shall be used as a guide in setting up safe separation distances between EEDs and the transmitting antenna of all RF emitters or determining the maximum power density allowable for an EED. These calculations are based on “worst-case” assumptions, such as EEDs with a maximum no-fire sensitivity of 50 mW and far-field conditions. The far field of the antenna provides a more consistent power density environment than that found in the near field. Distances greater than R_{ff} are considered far field. Distances less than or equal to R_{ff} are near field. The following formula can be used to determine where the far field begins:

$$R_{ff} = \frac{2D^2 f}{c}$$ where

R_{ff} = distance, in meters, from transmitting antenna where the far field begins
D = largest dimension of the antenna, meters
f = frequency (Hz)
c = speed of light, 3×10^8 m/s

B.1.1.5 For near field conditions, contact the Radiation Control Officer.

B.1.2 Safe Separation Distance Criteria (See Table B-1 and Figure B-1)

B.1.2.1 Use Worst Case or Unknown Configuration, when EEDs are unshielded, or the leads or circuitry could inadvertently be formed into a resonant dipole or loop antenna, or the configuration of the EEDs is unknown.

B.1.2.2 Use Exposed EEDs, when EEDs are exposed due to maintenance, assembly, or disassembly or the item or operational vehicle, which contains the EED, is exposed due to maintenance assembly, or disassembly.

B.1.2.3 Use Exposed EEDs in Storage or Ground Transport (Metal Container), when EEDs are stored or in a ground transport configuration inside a conductive (Metal Container). This includes EEDs assembled in an operational configuration when the exterior containment provides a conductive shield.

B.1.2.4 Use Exposed EEDs in Storage or Ground Transport (Non-metal Container), when EEDs are stored or in a ground transport configuration inside a nonconductive (non-metal) container or, Column B, Exposed EED, even though leadless EEDs are involved, since vehicle systems wiring could form a resonant antenna during installation.

B.1.2.5 Use EEDs In or On Aircraft, when EEDs or the item or operational vehicle containing them are in a transport configuration inside cargo aircraft or externally loaded on an aircraft.

B.1.2.6 Use Leadless EEDs, when EEDs do not have lead wires and are in the original shipping configurations and/or containers. This does not include handling and/or installing leadless EEDs (column B applies). When handling and installing EEDs, apply the distance listed in Figure B-1.

B.1.2.7 When unclear about the appropriate configuration and column to apply from Table B-1, use the most conservative; i.e., the greatest distance or largest power density.

B.1.3 Maximum Power Density Criteria

B.1.3.1 A power density and field intensity survey shall be made, when electrical characteristics of the EEDs are not known or when the minimum safe separation distances cannot be complied with because of lack of real estate or other limitations.

B.1.3.2 The measured power density shall be no greater than the recommended maximum power density. Compare the measured power density with the recommended maximum power density calculated from Table B-1.

B.1.3.3 When more than one transmitter is operating in an area, each at a different frequency, the maximum allowable power density is the greatest power density calculated for each of the transmitters.

B.1.3.4 Approximate calculations for safe separation distances can also be made using the nomograph provided in Figure B-1.

B.1.4 Use peak power for P_t except for pulsed systems with pulse widths less than one millisecond (ms). In this case, use the larger of 1) the average power or 2) (peak power) x (largest pulse width expressed in ms)/1 ms. Note: 1 ms = .001 seconds.

B.1.5 For EEDs with a no-fire sensitivity less than 50 mW and frequencies outside the ranges specified in Table B-1, contact NASA Headquarters, Chief, SMA.

Table B-1. Recommended EED Safe Separation Distances and Power Densities

"Worst-Case"	Maximum Allowable Power Density	Safe Separation Distance (SSD)
$f < 0.005\,MHz$	$P_o = 100\frac{W}{m^2}$	$D = 0.0925\sqrt{P_t G_t}$ ft
$0.005\,MHz < f < 2\,MHz$	$P_o = \left(\frac{0.05}{f}\right)^2 \frac{W}{m^2}$	$D = 18.5 f \sqrt{P_t G_t}$ ft
$2\,MHz < f < 80\,MHz$	$P_o = 6.25x10^{-4}\frac{W}{m^2}$	$D = 37.0\sqrt{P_t G_t}$ ft
$80\,MHz < f < 32000\,MHz$	$P_o = \left(\frac{f}{3200}\right)^2 \frac{W}{m^2}$	$D = \left(\frac{2960}{f}\right)\sqrt{P_t G_t}$ ft
$32000\,MHz < f$	$P_o = 100\frac{W}{m^2}$	$D = 0.0925\sqrt{P_t G_t}$ ft
"Exposed EED"	Maximum Allowable Power Density	Safe Separation Distance (SSD)
$f < 0.02\,MHz$	$P_o = 100\,W/m^2$	$D = 0.0925\sqrt{P_t G_t}$ ft
$0.02\,MHz < f < 2\,MHz$	$P_o = \left(\frac{0.2}{f}\right)^2 \frac{W}{m^2}$	$D = 4.625 f \sqrt{P_t G_t}$ ft
$2\,MHz < f < 48.5\,MHz$	$P_o = 0.01\,W/m^2$	$D = 9.25\sqrt{P_t G_t}$ ft
$48.5\,MHz < f < 4850\,MHz$	$P_o = \left(\frac{f}{485}\right)^2 \frac{W}{m^2}$	$D = \left(\frac{448.625}{f}\right)\sqrt{P_t G_t}$ ft
$4850\,MHz < f$	$P_o = 100\,W/m^2$	$D = 0.0925\sqrt{P_t G_t}$ ft
"In Storage or Ground Transport in a Non-Metallic Container"	Maximum Allowable Power Density	Safe Separation Distance
$f < 0.06325\,MHz$	$P_o = 100\,W/m^2$	$D = 0.0925\sqrt{P_t G_t}$ ft
$0.06325\,MHz < f < 2\,MHz$	$P_o = 10\times\left(\frac{0.2}{f}\right)^2 \frac{W}{m^2}$	$D = 4.625 f \sqrt{\frac{P_t G_t}{10}}$ ft
$2\,MHz < f < 48.5\,MHz$	$P_o = 0.1\,W/m^2$	$D = 2.925\sqrt{P_t G_t}$ ft
$48.5\,MHz < f < 1533.7\,MHz$	$P_o = 10\times\left(\frac{f}{485}\right)^2 \frac{W}{m^2}$	$D = \left(\frac{448.625}{f}\right)\sqrt{\frac{P_t G_t}{10}}$ ft
$1533.7\,MHz < f$	$P_o = 100\,W/m^2$	$D = 0.0925\sqrt{P_t G_t}$ ft
"In Storage or Ground Transport in a Metallic Container" Or "In or On an Aircraft"	Maximum Allowable Power Density	Safe Separation Distance
All Frequencies	$P_o = 100\,W/m^2$	$D = 0.0925\sqrt{P_t G_t}$ ft
Leadless EED	Maximum Allowable Power Density	Safe Separation Distance
All Frequencies	N/A	$D = 10$ ft

(Reference: AFMAN91-201, January 2013)

NOTES:

D = distance (ft.); f = frequency (MHz); P_t = transmitter power (W);
P_o = maximum power density (W/m^2); G_t = antenna gain. To convert from G (dB), use $G_t = \log^{-1}[G(dB)/10]$

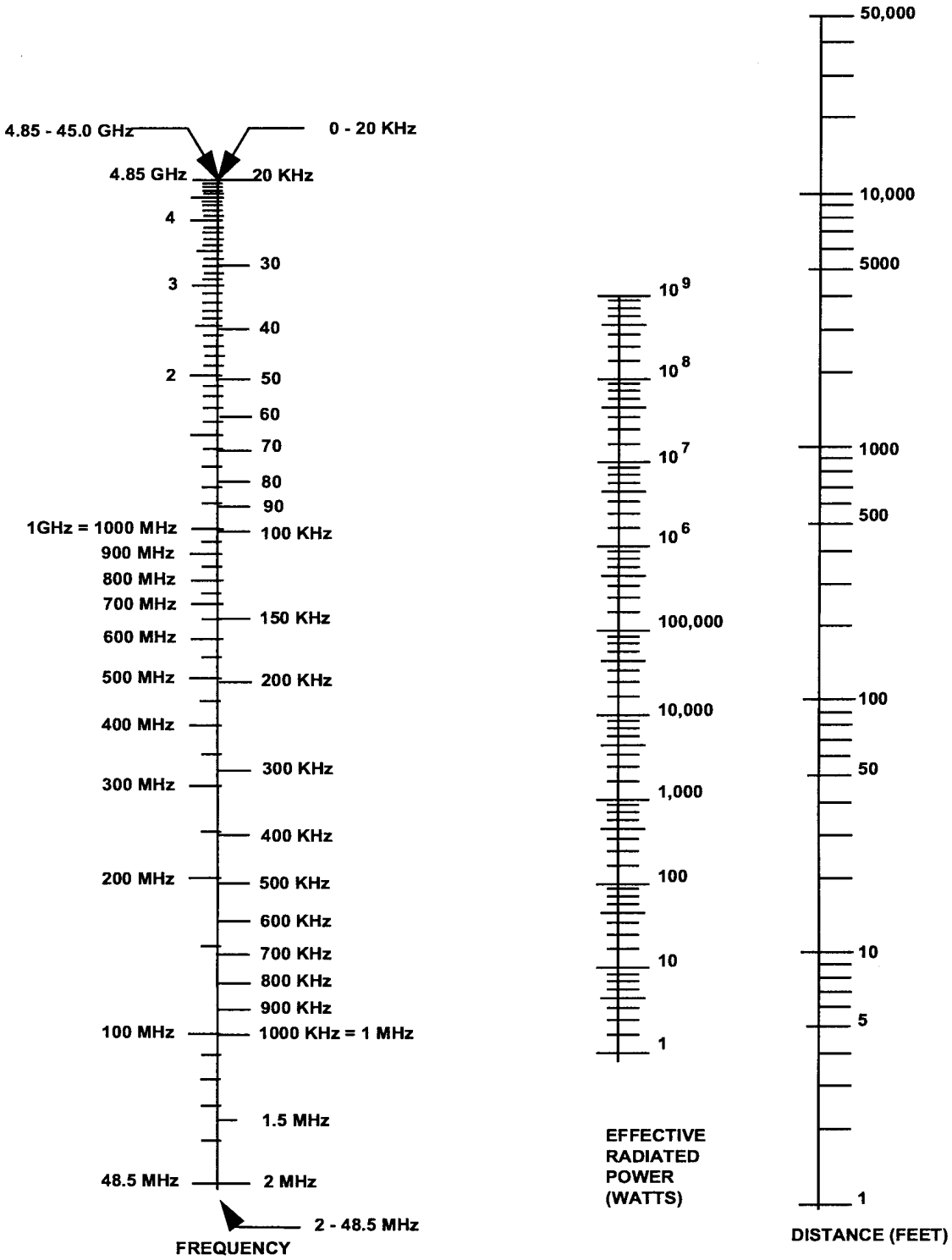

Figure B-1. Recommended Safe Separation Distances for EEDs in Exposed Condition
(Reference: AFMAN91-201, January 2013)

APPENDIX C. TRAINING

Plan of Instruction	ESO	Ordnance Handler
Review NASA Agency Documentation		
NPR 1600.1 Security Program Procedural Requirements	R	
NPR 8715.3 NASA General Safety Program Requirements	R	
NPR 8621.001 Procedural Requirements for Mishap and Close Call Reporting, Investigating and Recordkeeping	R	R
NASA STD 8719.11 Safety Standard for Fire Protection	R	
NASA STD 8709.2, Management of Safety and Mission Assurance Technical Authority (SMA TA) Requirements	R	
Review National Fire Protection Association Documentation		
NFPA 70 National Electrical Code	R	
NFPA 70E Standard for Electrical Safety in the Workplace	R	
NFPA 101 Life Safety Code	R	
NFPA 400 Hazardous Materials Code	R	
NFPA 495 Explosive Materials Code	R	
NFPA 704 Standard System for the Identification of the Hazards of Materials for Emergency Response	R	
NFPA 780 Standard for the Installation of Lightning Protection Systems	R	
Review Occupational Safety & Health Administration (OSHA) Documentation		
49 CFR Part 172	R	
29 CFR 1910.109	R	
Safety Training		
SATERN		
NASA Basic Explosive Safety Training w/Center Specific Module (NASA-EXPL-SAFE-101)[1] (Instructor Led)	R	R
NASA Basic Explosive Safety Refresher Training w/Center Specific Module (SMA-HQ-WBT-221)[2] (Online)	R	R
Explosive Safety Management Course (SMA-HQ-WBT-222)	R	R
Introduction To Human Factors in Mishap and Close Call Investigation (SMA-001-07)[1] (Online)	R	
Overview of Mishap Investigations (SMA-002-07)[1] (Online)	R	
Mishap Investigation Roles and Responsibilities (SMA-002-08)[1] (Online)	R	
Completing the Investigation and Mishap Report (SMA-002-09)[1] (Online)	R	
Introduction to Root Cause Analysis (SMA-002-10) (Online)	R	
Risk Management Overview (SMA-OV-WBT-111) (Online)	R	
Systems Engineering Overview (SMA-OV-WBT-113) (Online)	X	
Basics of Reliability and Maintainability (SMA-RM-WBT-100) (Online)	R	
Human Factors in Mishap Investigation (SMA-SAFE-OSMA-4004) (Instructor Led)	X	
Basics of System Safety (SMA-SS-WBT-100) (Online)	R	
Classroom Training[3]		
Basic Electrostatic Discharge (ESD) Course	R	
Basic Electromagnetic Interference (EMI) Course	R	
Intro into Industrial Hygiene Course	R	
Process Safety Management Course [4]	R	
Chemistry of Explosives Course	R	
Basic Pyrotechnic Course	X	
Specialized Training		
Course/Knowledge Specific to the Type(s) of Hazardous Material	R	R
On the Job Training Specific to the Type(s) of Hazardous Material	R	R

R – Required
X – Recommend

1 - Required every three (3) years.
2 - Online Refresher (SMA-HQ-WBT-221) course can be substituted for the Instructor Led (NASA-EXPL-SAFE-101) course every other required timeframe. (See Center ESO for Center Specific Module Requirement).
3 - NASA, Department of Defense, other government agency, University or other creditable instructor led course.
4 - As pertains to your Center.

APPENDIX D. REFERENCES

D.1 Purpose

The purpose of this appendix is to provide guidance and is made available in the reference documents below. The following documents are considered to be useful as background information for the reader in understanding the subject matter but do not constitute requirements of the standard.

D.1.1 Government Documents

6 CFR Part 27	Chemical Facility Anti-Terrorism Standards
27 CFR-II-C-555	Commerce in Explosives
29 CFR-1910.103	Hydrogen
29 CFR-1910.307	Hazardous (classified) Locations
29 CFR 1910.1200	Hazard Communication
ATF	Federal Explosives Law and Regulations
NPR 1620.3	Physical Security Requirements for NASA Facilities and Property
NPR 8715.3	NASA General Safety Program Requirements
NASA-STD-8709.22	Safety and Mission Assurance Acronyms, Abbreviations, and Definitions
HNC-ED-CS-98-1	U.S. Army Corps of Engineers Reports
HNC-ED-CS-98-2	U.S. Army Corps of Engineers Reports
Technical Paper 13	Prediction of Building Debris for Quantity-Distance Siting, Department of Defense Explosives Safety Board
Technical Paper 14	Risk-Based Explosives Safety Analysis

D.1.2 Non-Government Documents

AIAA SP-084-1999	Fire, Explosion, Compatibility and SafetyHazards of Hypergols – Hydrazine
AIAA SP-085-1999	Fire, Explosion, Compatibility and SafetyHazards of Hypergols – Monomethylhydrazine
AIAA SP-086-2001	Fire, Explosion, Compatibility and SafetyHazards of Nitrogen Tetroxide
ANSI/AIAA-G-095	Guide to Safety of Hydrogen and Hydrogen Systems

ANSI /ISEA Z87.1	American National Standard for Occupational and Educational Personal Eye and Face Protection Devices
AFRPL-TR-67-124	“Investigation of the Explosive Potential of the Hybrid Propellant Combinations N2O4/PBAN and CTF/PBAN,” 1967, (AD A003 595), Wilton, C.
ASTM F150	Standard Test Method for Electrical Resistance of Conductive and Static Dissipative Resilient Flooring
ASTM F2413	Standard Specification for Performance Requirements for Foot Protection
CPIA Publication 394	Hazards of Chemical Rockets and Propellants, Volume III

Engineering Guide, Predicting 1st and 2nd Degree Skin burns from Thermal Radiation, March, 2000, Society of Fire Protection Engineers (SFPE) Engineering Guide

NFPA 45	Standard on Fire Protection for Laboratories Using Chemicals
NFPA 69	Standard on Explosion Prevention Systems
NFPA 70	National Electrical Code
NFPA 77	Recommended Practice on Static Electricity
NFPA 251	Standard Methods of Tests of Fire Resistance of Building Construction and Materials
NFPA 400	Hazardous Materials Code
NFPA 505	Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation
NFPA 704	Standard System for the Identification of the Hazards of Materials for Emergency Response

APPENDIX E. K-FACTORS

E.1 K-Factor: K is a constant that is used to determine separation distance by the formula $d = KW^{1/3}$, where W is the weight in pounds. The formula can be used to determine required distances between potential explosive sites (PESs) and exposed sites (ESs).

Table E-1. K-Factors and Associated pressures/QD distances

K value	Overpressure (psi)	Exposure consequence/QD distance
1.79	386.9	Lethality due to lung rupture
2	360	
3.33	107.1	Lethality due to lung rupture
3.9	74.4	99% chance of eardrum rupture
6	27	Barricaded Above ground, Inter-Magazine Distance (IMD)
8	15	50% chance of eardrum rupture
9	12.0	Interline Distance (ILD) w/barricading
10.3	9	20% chance of eardrum rupture
11	8	Un-barricaded Aboveground Inter-Magazine Distance
12.2	6.6	10% chance of eardrum rupture
14.6	4.9	5 % chance of eardrum rupture
17.9	3.6	2% chance of eardrum rupture
18	3.5	ILD w/o barricades
20	3	Eardrum rupture
24	2.3	Public Traffic Route
28	1.9	
30	1.7	Public Traffic Route
40	1.2	Inhabited Building Distance
50	0.9	Inhabited Building Distance

E.1.1 K-Factor = 6 (Barricaded Aboveground Magazine Distance (27 psi)

a. Unstrengthened buildings will be destroyed completely.

b. Personnel at this distance or closer will be killed by direct action of blast, by being struck by building debris, or by impact against hard surfaces.

c. Transport vehicles will be overturned and crushed by blast.

d. Explosives loaded vessels will be damaged severely, with propagation of explosion likely.

e. Aircraft will be destroyed by blast, thermal, and debris effects.

E.1.2 K= 9 Barricaded ILD (12 psi)

a. Unstrengthened buildings will suffer severe structural damage approaching total destruction.

b. Severe injuries or death to occupants of the ES may be expected from direct blast, building collapse, or translation.

c. Aircraft will be damaged beyond economical repair both by blast and fragments. If the aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.

d. Transport vehicles will be damaged heavily, probably to the extent of total loss.

e. Direct propagation of explosion between two explosives locations is unlikely when barricades are interposed between them to intercept high velocity low angle fragments.

f. Improperly designed barricades or structures may increase the hazard from flying debris or may collapse in such a manner as to increase the risk to personnel and equipment.

E.1.3 K= 11 Unbarricaded Aboveground Magazine Distance (8 psi)

a. Unstrengthened buildings will suffer damage approaching total destruction.

b. Personnel are likely to be injured seriously due to blast, fragments, debris, and translation.

c. There is a 20 percent risk of eardrum rupture.

d. Explosives loaded vessels are likely to be damaged extensively and delayed propagation of explosion may occur.

e. Aircraft will be damaged heavily by blast and fragments; destruction by ensuing fire is likely.

f. Transport vehicles will sustain severe body damage, minor engine damage, and total glass breakage.

E.1.4 K= 18 Unbarricaded ILD (3.5 psi)

a. Direct propagation of explosion is not expected.

b. There is some possibility that delayed communication of an explosion may occur from fires, or as a result of equipment failure at the ES.

c. Damage to unstrengthened buildings will be of a serious nature and approximately 50 percent or more of the total replacement cost.

d. There is a 1 percent chance of eardrum damage to personnel.

e. Personnel injuries of a serious nature are likely from fragments, debris, firebrands, or other objects.

f. Cargo ships would suffer damage to decks and superstructure from being struck by fragments and having doors and bulkheads on the weather deck buckled by overpressure.

g. Aircraft can be expected to suffer considerable structural damage from blast. Fragments and debris are likely to cause severe damage to aircraft at distances calculated from the formula 18W1/3 when small quantities of explosives are involved.

h. Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter resistant window glass.

i. Control. Many situations arise in which control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical. Use of such construction to withstand blast overpressure is encouraged if it is more economical than distance alone, or if sufficient distance is not available to prevent the overpressure from exceeding this level.

E.1.5 K= 24 Public Traffic Route Distance (< 100,000 lbs. HE) (2.3 psi)

a. Unstrengthened buildings can be expected to sustain damage approximately 20 percent of the replacement cost.

b. Occupants of exposed structures may suffer temporary hearing loss or injury from secondary blast effects such as building debris and the tertiary effect of displacement.

c. Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments & debris, depending largely on the PES structure and amount of ammunition & fragmentation characteristics thereof.

d. Vehicles on the road are likely to suffer little damage unless hit by a fragment or unless the blast wave causes momentary loss of control.

e. Aircraft are likely to suffer some damage to appendages and sheet metal skin from blast and possible fragment penetration; however, the aircraft may be expected to be operational with minor repair.

f. Cargo type ships are likely to suffer minor damage to deck structure and exposed electronic gear from blast and possible fragment penetration, but such damage may be expected to be readily repairable.

g. Control. The risk of injury or damage due to fragments for limited quantities of explosives at the PES can be reduced by barricading. Also, many situations arise when control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical.

E.1.6 K= 30 Public Traffic Route Distance (> 250,000 lbs. HE) (1.7 psi)

a. Unstrengthened buildings can be expected to sustain damage approximately 10 percent of the replacement cost.

b. Occupants of exposed unstrengthened structures may suffer injury from secondary effects such as building debris.

c. Aircraft in landing and takeoff status may lose control and crash.

d. Parked military and commercial aircraft likely will sustain minor damage due to blast but may be expected to remain airworthy.

e. Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and fragmentation characteristics thereof.

f. Control. The risk of injury or damage due to fragments for limited quantities of explosives at the PES may be reduced by barricading or application of minimum fragment distance requirements.

E.1.7 K= 40 (1.2 psi) OR K= 50 (0.9 psi) Inhabited Building Distance

a. Unstrengthened buildings can be expected to sustain damage up to about 5 percent of the replacement cost.

b. Personnel in buildings are provided a high degree of protection from death or serious injury, with injuries that do occur principally being caused by glass breakage and building debris.

c. Personnel in the open are not expected to be injured seriously directly by the blast. There could be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and the fragmentation characteristics thereof.

d. Control. Glass breakage and structural damage can be reduced by means such as orientation by keeping the surface area of exposed glass panels to a minimum and the use of blast-resistant windows.

Table E-2. Expected Peak Incident Pressures from HD 1.1 Events

K-FACTOR ($ft/lb^{1/3}$)	INCIDENT PRESSURE (psi)	K-FACTOR ($ft/lb^{1/3}$)	INCIDENT PRESSURE (psi)
1.0	1006	20	3.0
1.2	766	21	2.8
1.4	598	22	2.6
1.6	475	23	2.5
1.8	384	24	2.3
2.0	314	25	2.2
2.5	200	26	2.1
3.0	135	27	2.0
3.5	96	28	1.9
4.0	70	29	1.8
4.5	54	30	1.7
5.0	42	31	1.6
6	27	32	1.6
7	20	33	1.5
8	15	34	1.5
9	12	35	1.4
10	9.6	36	1.4
11	8.0	37	1.3
12	6.9	38	1.3
13	6.0	39	1.2
14	5.3	40	1.2
15	4.7	45	1.0
16	4.2	50	0.9
17	3.8	60	0.7
18	3.5	70	0.6
19	3.2	80	0.5